F. X. BROWNE ASSOCIATES, INC.

FEASIBILITY STUDIES OF LOON LAKE AND GOOSE LAKE

FINAL REPORT

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Presented to:

The Indiana Lake Enhancement Program
Indianapolis, Indiana 46204

Prepared for:

The Loon Lake Property Owners Association
and
The Goose Lake Association

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Executive Summary

This report presents the water quality and modeling results for Indiana "T by 2000" Lake Enhancement Program Phase I studies of Loon Lake and Goose Lake. Management alternatives for lake restoration are discussed and general recommendations have been made.

Conclusions

Loon Lake

1. There was essentially no dissolved oxygen within the bottom waters of the lake, below a depth of 13 feet (4 meters). This low dissolved oxygen, coupled with an observed high concentration of total phosphorus in the bottom waters of the lake indicate that internal loading of phosphorus from the sediments may be significant.

2. Highest pH values were at the surface as a result of the photosynthetic activity of phytoplankton (algae) in the lake.

3. The lake contained a relatively high chlorophyll a concentration and phytoplankton density, with bluegreen algae comprising nearly 100 percent of the population. These bluegreen algae, *Anabaena*, *Aphanizomenon*, *Oscillatoria*, and *Microcystis*, are notorious for producing algal blooms in eutrophic lakes.

4. The lake contained high concentrations of both nitrogen and phosphorus. Phosphorus was the limiting nutrient (that nutrient whose concentration controls algal growth).

5. Macrophytes were abundant in shallower parts of the lake, growing to a depth of around five feet. The macrophyte population was fairly balanced. Coontail (*Ceratophyllum*) and milfoil (*Myriophyllum*) were the species present with the greatest potential for a negative impact on recreational activities. These plants are currently controlled to some degree by chemicals.

6. Based on the IDEM eutrophic index, the lake scored 53 to 56 eutrophy points and therefore classified as a Class III (advanced eutrophic) waterbody. The 1990 IDEM index value of 53 to 56 is higher than the 1974 IDEM value of 46 and the 1988 IDEM value of 33. The 1990 value was determined as part of this study, while the 1974 and 1988 values were reported by the Indiana Department of Environmental Management. It must be kept in mind, however, that these values are only represented by a one-day sampling event and the above differences in eutrophy points may be due to natural variability. The lake is also classified as eutrophic by EPA standards and according to the Carlson Trophic State Index.

7. Pollutant loading (nutrients and suspended solids) are entirely from non-point sources. Septic systems account for 7 percent of the phosphorus load and 9 percent of the nitrogen load to the lake.

8. Phosphorus loading reductions of 90 percent would be required to improve water quality to mesotrophic levels.

Goose Lake

1. There was essentially no dissolved oxygen within the bottom waters of the lake, below a depth of 13 feet (4 meters). This low dissolved oxygen, coupled with an observed high concentration of total phosphorus in the bottom waters of the lake indicate that internal loading of phosphorus from the sediments may be significant.

2. Highest pH values were at the surface as a result of the photosynthetic activity of phytoplankton (algae) in the lake.

3. The lake contained a relatively high chlorophyll a concentration and phytoplankton density, with bluegreen algae comprising nearly 100 percent of the population. These bluegreen algae, *Anabaena*, *Aphanizomenon*, *Oscillatoria*, and *Microcystis*, are notorious for producing algal blooms in eutrophic lakes.

4. The lake contained high concentrations of both nitrogen and phosphorus. Phosphorus was the limiting nutrient (that nutrient whose concentration controls algal growth).

5. Macrophytes were abundant in shallower parts of the lake, growing to a depth of around five feet. The macrophyte population was fairly balanced. Coontail (*Ceratophyllum*) and milfoil (*Myriophyllum*) were the species present with the greatest potential for a negative impact on recreational activities. These plants are currently controlled to some degree by chemicals.

6. Based on the IDEM eutrophic index, the lake scored an IDEM index value of 49 to 52 eutrophy points and is therefore is classified as a Class II/III (intermediate to advanced eutrophic) waterbody. The above range of values is based on water quality data on August 18, 1990. This range of values is lower than the 1974 IDEM value of 61 and is higher than the 1990 IDEM value of 40. The index values of 61 and 40 were reported by the Indiana Department of Environmental Management. Of special interest, the index value of 40 was based on water quality data collected on July 3, 1990. It must be kept in mind, however, that these values are only represented by a one-day sampling event and the above differences in eutrophy points may be due to natural variability. The lake is also classified as eutrophic by EPA standards and according to the Carlson Trophic State Index.

7. Pollutant loading (nutrients and suspended solids) are entirely from non-point sources. Septic systems account for 13 percent of the phosphorus load and 18 percent of the nitrogen load to the lake.

8. Phosphorus loading reductions of 85 percent would be required to improve water quality to mesotrophic levels.

Recommendations

Institutional

The Loon Lake Property Owners Association and The Goose Lake Association should combine their efforts by establishing a watershed management district, which would serve the entire Loon and Goose Lakes watershed region. The watershed management district may be set-up as a non-profit organization or as a conservancy district. One advantage in establishing the watershed management district as a conservancy district is that the watershed management district would have taxing powers. In any event, the watershed management would be responsible for overseeing all activities that may impact the water quality of Loon and Goose Lakes.

The advisory committee (or board of directors) of the watershed management district should include all appropriate government representatives, other people who can offer valuable technical and planning expertise, and at least one representative from the Loon and Goose Lake Associations. The functions of the watershed management district would be as follows: 1) coordination of effort among Whitley and Noble Counties to accomplish watershed and lake management activities, 2) provision of technical and advisory assistance to local governments, homeowners, businesses, developers, and farmers, 3) development of model programs and ordinances, including erosion and sedimentation ordinances for new construction and a stormwater runoff ordinance to control water quality and flooding, 4) prioritization of watershed and lake management activities, which encompass the implementation of best management practices within the watershed, and further lake and watershed studies, and 5) financial management of lake and watershed programs, which includes the acquisition of state, federal and private funds to be used for various projects throughout the watershed.

The watershed management district should develop educational materials and conduct educational programs for regulatory people, school children, and the public at large. One important activity which should be part of the educational program is a "Watershed Watch" program. An educational fact sheet could be distributed which describes potential pollutant sources (eroding land, gasoline, oil, or chemical spills, etc.), and gives a telephone number to contact if someone sees a possible problem.

The watershed management district would also be involved in land use planning activities which would protect or improve the water quality in Loon and Goose Lakes. Such activities might include land acquisition, conservation easements, and land trusts.

The watershed management district along with the assistance of the Whitley and Noble Counties Soil and Water Conservation Districts (SWDC), the Soil Conservation Service (SCS), and the Agricultural Stabilization and Conservation Service (ASCS), should develop model erosion control and stormwater runoff control ordinances for adoption by both Whitley and Noble Counties.

Watershed Management Plan

Watershed management practices should be targeted at areas identified by AGNPS modeling and field investigations. The most applicable watershed management practices include:

Agricultural Management Practices

Conservation tillage (no-till in combination with integrated pest management to minimize pesticide and chemical runoff)

Cover cropping where not already practiced

Critical area planting - establishing permanent vegetation on areas subject to high erosion

Terraces on lands where slope conditions allow

Grassed waterways on all drainage swales

Farmland management practices, where applicable, including pastureland management, livestock watering facilities, and fencing

Agricultural waste storage facilities and management of waste application

Buffer strips along nearly every foot of stream/ditch

Impoundment ponds to collect sediment and nutrients where terraces are not applicable

Institution of strict septic system management, which includes frequent pumping and the identification and remediation of failing septic systems

Homeowner Management Practices

Routine maintenance of septic systems is critical in maintaining high water quality. Failing septic systems should be identified by septic leachate studies and/or on-site inspections by the watershed management district with the cooperation of the county health departments. Failing systems should be repaired and where clusters of failing systems are identified, the installation of small community treatment systems may be required.

The use of pesticides and lawn fertilizers should be kept to a minimum and applied during the times when runoff is minimized.

All exposed soils should be reseeded, thereby reducing sediment loadings to nearby watercourses.

In areas where lawns and watercourses are contiguous, homeowners should establish buffer strips. Buffer strips may consist of ornamental tree and shrub plantings that separate the lake or stream bank from lawned areas.

Streambank and Roadway Stabilization Practices

Streambanks, exhibiting signs of moderate to severe soil erosion, should be stabilized using vegetative controls or structural controls.

Shoulders of roadways, exhibiting signs of moderate to severe soil erosion, should be stabilized using vegetative controls or structural controls.

Wastewater Management Practices

A wastewater feasibility study should be performed at Loon Lake and Goose Lake. The feasibility study should investigate various treatment options, land application of the wastewater effluent, and the cost effectiveness of a joint system with other lakes in the watershed such as New Lake and Old Lake.

Impoundment Ponds

A wetland basin with a surface area of at least 12 acres and an average depth of 3.5 feet should be constructed on Friskney Ditch close to where it enters Loon Lake. A basin of this size would remove an estimated 90 percent of the sediment and 60 percent of the phosphorus load carried by the stream.

In-Lake Management Practices

Loon Lake

In-lake management is primarily geared towards managing aquatic macrophyte abundance in an environmentally sound manner. The present strategy is primarily chemical application, with some hand pulling. An integrated approach is recommended that combines harvesting, hand-pulling and the installation of bottom barriers. Macrophyte populations should be allowed to occur naturally in those areas where they do not immediately impact recreational use of the lake.

If nutrient loading from the watershed can be sharply reduced, internal phosphorus loading from the sediments may provide the bulk of the remaining phosphorus load to the lake. Nutrient inactivation using aluminum salts should be reevaluated at that time to minimize sediment phosphorus release and improve lake water quality.

Goose Lake

In-lake management is primarily geared towards managing aquatic macrophyte abundance in a environmentally sound manner. The present strategy is primarily chemical application, with some hand pulling. An integrated approach is recommended that combines harvesting, hand-pulling and the installation of bottom barriers. Macrophyte populations should be allowed to occur naturally in those areas where they do not immediately impact recreational use of the lake.

If nutrient loading from the watershed can be sharply reduced, internal phosphorus loading from the sediments may provide the bulk of the remaining phosphorus load to the lake. Nutrient inactivation using aluminum salts should be considered at that time to minimize sediment phosphorus release and improve lake water quality.

1.0 Project Description

1.1 Background

Loon and Goose Lakes are located in northwest Whitley County, in northeastern Indiana (Figure 1.1). The latitude and longitude coordinates for Goose Lake are 41° 14' 20" North and 85° 33' 12" West; coordinates for Loon Lake are 41° 16' 19" North and 85° 32' 18" West. The southern border of the Goose Lake watershed separates the Tippecanoe drainage basin in Noble, Kosciusko, and northwest Whitley Counties from the Eel River drainage basin in central an southern Whitley County. Goose Lake drains to Loon Lake through Winters Ditch. Loon Lake drains into the Upper Tippecanoe River, just southwest of Ormas, through a short (2,000 foot) outlet, Schaefer Drain. The Tippecanoe River travels southwest through nine other counties before it converges with the Wabash River north of Lafayette, IN. The Wabash River forms the southwest border between Indiana and Illinois before joining the Ohio River where Illinois, Indiana and Kentucky meet.

The 9.6 square-mile watershed consists primarily of agricultural land. Corn, soybeans, wheat, and forage are the main crops. A few dairy farms and small hog and beef operations are also present within the watershed. The watershed contains numerous small wetlands in depressions. The only town in the watershed is the small town of Etna, with a population of about 75 people, located one and on-half miles west of Loon Lake. Columbia City, the Whitley county seat, has a population of 5,686 (1990 projection) and is located about 6 miles southeast of Goose Lake.

Approximately eighty percent of Loon Lake's shoreline is occupied by residential development. There are 196 lakefront homes, 63 houses set back from shoreline property, and a 17-unit planned subdivision west of Brown Road (Pearson, 1989; Ted Hege, personal communication). Undeveloped shoreline areas include wetlands which surround the southeast arm of the lake near the mouth of Friskney Ditch, adjacent to the public access site, and an undeveloped area along the eastern shore, near the site of a former commercial campground.

For Goose Lake, about one-third of the northwestern shoreline is occupied by residential homes, while the southeastern shore remains undeveloped largely due to the presence of wetland areas. There are 28 lakefront homes plus 50 houses set back from the lake's shoreline. In addition to the above single family dwellings, a trailer park consisting of 20 units plus a restaurant are located in close proximity to Goose Lake.

In the Loon and Goose Lakes watershed area, private land programs under the Indiana Department of Natural Resources (IDNR), Division of Fish and Wildlife are well received. Under the IDNR Division of Fish and Wildlife, there are three types of private land programs in the Loon and Goose study area: the Classified Wildlife Areas program, the Gamebird program, and the Cost-Share program. The primary goal of each of these state programs is to improve and increase the suitable habitat for various types of wildlife.

The Classified Wildlife Areas program provides tax incentives to landowners, who elect to set aside tracts of land as wildlife refuges. As of January 1991, there were approximately 31 and 14 classified wildlife areas in Noble and Whitley Counties, respectively. The Gamebird and Cost-Share programs were designed to create wildlife habitat on private tracts of land. In the Gamebird program, landowners with the assistance from the state create habitat for fowl of interest by establishing habitat, such as, windbreaks and foodplots. In the Cost-Share program, shallow wetland areas are created as wildlife habitat. As the name of this program implies, the project costs are shared by both the landowner and the state.

Within the watershed, two sites may be significant natural areas. The first site is a tamarack swamp (approximately 54 acres), located on the southwestern shoreline of Goose Lake. Historical records indicate that fourteen state listed plant species were once identified. In the early 1980's, fieldwork failed to relocated any of these species. It is speculated that hydrologic changes in this bog have resulted in changes within the plant community. The other site is a sandy marl beach (approximately 13 acres) along the northern shoreline of New Lake. Historical records indicate that one state listed species, *Spiranthes lucida* (early ladies-tresses) was recorded in 1924. Early ladies-tresses is classified as a threatened (ST) by the state and has no federal status listing. If this species is still extant, the sandy marl beach may be a significant natural area. For both Loon and Goose Lakes, only *Potamogeton friessii* (Frie's pondweed) is a state listed species and is located in Goose Lake. Frie's Pondweed is classified as endangered (SE) by the state, has no federal status, and has no reported date of record for the state listing (IDNR, Division of Nature Preserves, personal communication).

In the past, fishery and aquatic macrophyte information has been obtained at both Loon and Goose Lakes. From 1971 to 1988, twenty-six different species of fish have been collected in Loon Lake during five population surveys. Fish population surveys were conducted by IDNR's Division of Fish and Wildlife (Pearson, 1989). Based on these surveys, bluegills, yellow perch and largemouth bass were identified as the dominant fish species. Secondary sport fish are catfish, sunfish and their hybrids, black crappie and tiger muskellunge. The primary forage fish are chubsuckers, brook silversides and golden shinners (Pearson, 1989). As noted by Person (1989), little quantitative information on aquatic plant abundance in Loon Lake is available. In 1977, stonewort (*Chara spp.*) and coontail were the dominant submergent macrophytes, while cattail, spatterdock and white water lily were common emergent macrophytes. According to Pearson (1989), macrophytes in the lake are neither "scarce nor abundant". In 1969, a fish population survey was conducted in Goose Lake by the INDR Division of Fish and Wildlife (Hudson, 1969). As part of this fish survey, aquatic macrophytes were identified. In Goose Lake, thirteen different fish species were collected and the dominant fish species were bluegill, chubsucker, largemouth bass, yellow perch and redear (Hudson, 1969). Thirteen species of aquatic macrophytes were also identified in Goose Lake. Submergent plant species were abundant and considered a problem in the lake. In the Goose Lake Fish Management Report, it was recommended that aquatic vegetation controls should be initiated since this dense vegetative growth "provides unnecessary protection for smaller fishes" (Hudson, 1969).

Water quality in Loon and Goose Lakes has deteriorated over the years as a result of increased shoreline development and recreational use, and due to runoff from agricultural operations within the watershed. While water quality is better in Loon Lake than in Goose Lake, both lakes experience blue-green algae blooms and oxygen depletion.

Both Loon Lake and Goose Lake were included in the Indiana Lake Classification Surveys conducted by the Indiana Department of Environmental Management in 1975. Based on water quality data collected from IDEM survey, Goose and Loon Lakes scored 61 and 46 eutrophic points, respectively (Pearson, 1989). The IDEM eutrophic index rates lake water quality on a scale of 0 to 75 eutrophy points, where intermediate water quality ranges from 26 to 50 eutrophy points and lowest water quality is considered 51 to 75 eutrophy points. Concern about the future of water quality in the lakes inspired cooperation among the two separate lake associations. The Loon Lake Property Owners Association and the Goose Lake Association applied for a grant to include the two lakes in a feasibility study under the Indiana Lake Enhancement Program, administered by Indiana Department of Natural Resources Division of Soil Conservation as part of the overall "T by 2000" program. The grant was awarded in July of 1990.

1.2 Project Objectives

This study was conducted under the Indiana DNR "T by 2000" Lake Enhancement Program. It was designed in accordance with specific requirements of the Lake Enhancement Program, and with procedures used in Phase I Diagnostic-Feasibility studies conducted under state and federal clean lakes programs. A diagnostic-feasibility study is typically conducted in two stages. The diagnostic portion of the study is conducted to determine water quality conditions in the lake, identify existing problems, and determine the pollutant sources that are responsible for the observed problems. The feasibility aspect of the study involves the development of alternative restoration programs based on the results of the diagnostic study. These alternatives can include watershed management practices and in-lake restoration methods.

The primary objectives of the "T by 2000" Lake Enhancement Study for Loon and Goose Lakes were:

1. To identify the sources and magnitude of pollutants entering each lake and recommend specific management controls,

2. To develop and recommend a lake and watershed management program that is cost-effective, environmentally sound, and acceptable to the public,

3. To develop conceptual design information for the recommended management plan, and

4. To provide sufficient information for the implementation of the recommended lake and watershed management plan.

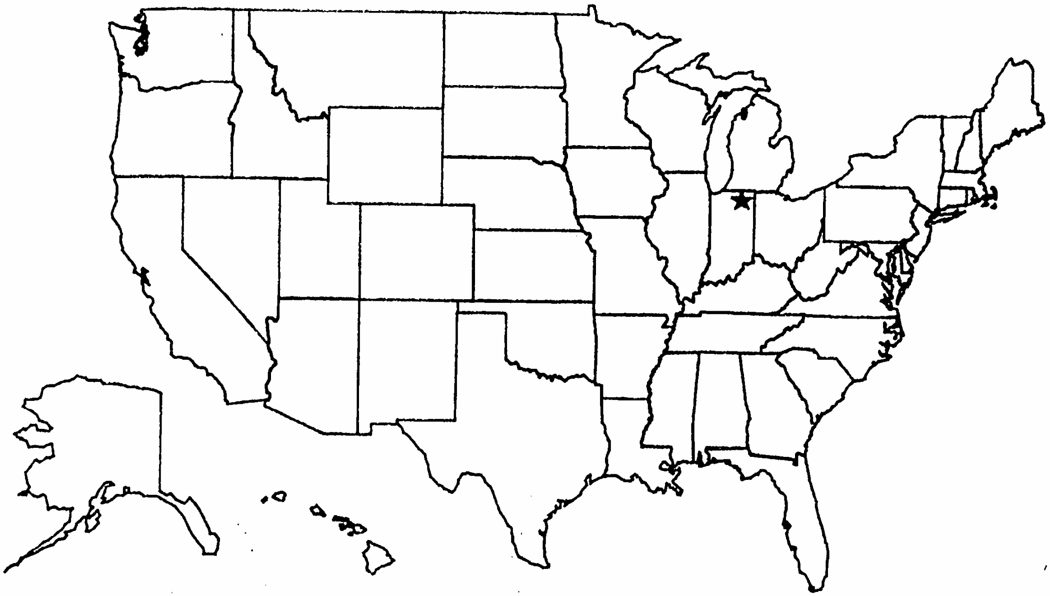

FIGURE 1.1

LOCATION MAP OF LOON & GOOSE LAKES IN NORTHEAST INDIANA

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2.0 Lake and Watershed Characteristics

2.1 Lake Morphology

Lake surface area, depth, volume, and watershed acreage is presented for each study lake in Table 2.1. The watershed area for Goose Lake is included in the Loon Lake watershed area.

Table 2.1
Lake and Watershed Characteristics of Loon and Goose Lakes

Parameter	Goose Lake	Loon Lake
Surface Area	84 acres	222 acres
Maximum Depth	69 feet	92 feet
Mean Depth	26 feet	26 feet
Lake Volume	710 million gallons	1,868 million gallons
Watershed Area (does not include lake)	922 acres (1.44 square miles)	6,163 acres (9.63 square miles)
Watershed Area:Lake Surface Area	10.9	28.1

Some values in Table 2.1 differ from previous reports as a result of information developed during the current study. Lake surface areas, lake volumes, and maximum depths are from IDNR bathymetric maps (1957). Mean depth was calculated by dividing lake volume by lake surface area. Watershed surface areas were determined by planimetry using USGS 7.5 minute series quadrangles.

2.2 Benefits and Recreational Use of Loon and Goose Lakes

2.2.1 Present Lake Uses

Loon and Goose Lakes provide recreational opportunities for residents of Whitley and Noble Counties, and for tourists from cities and outlying areas in Indiana and Ohio. Because Loon and Goose Lakes are near the southern limit of the Indiana natural lakes region, many visitors come from populated areas further south such as Columbia City, Fort Wayne, and Huntington. Summer recreational activities include boating, fishing, swimming, and camping. Boating opportunities range from canoeing the shallow wetland areas and fishing from small craft, to water skiing on Loon Lake. In the winter, the lakes are used for ice fishing, ice boating, and skating.

The Indiana Department of Natural Resources maintains a public access area for parking and boat launch at the tip of the southeast arm of Loon Lake. Public access to Goose Lake is provided by a boat ramp at the Goose Lake Resort near the outlet along the north shore.

2.2.2 Impairment of Recreational Uses

During the summer months, recreational use and the aesthetic value of Loon and Goose Lakes are to some degree impaired by blooms of algae and the growth of aquatic macrophytes. Generally in the months of July through August, shore fishing is limited by stands of aquatic macrophytes. These dense stands of aquatic macrophytes have also hampered boating activities near the lakes' shoreline areas. In addition to the above restrictions, the degradation of aquatic macrophytes, which have been washed-up on the lakes' shoreline areas, have been attributed to odor problems.

For some of the tributaries to these lakes, sedimentation has been another problem. Dissolved oxygen depletion and high phosphorus levels have been identified as the main sources to many of the observed water quality problems in these lakes.

2.3 Bathymetric Survey

For Loon and Goose Lakes, bathymetric and sediment profile maps were developed as part of this study. Using a fathometer, both water and sediment depth data were collected via boat along transects in August of 1990. For Loon and Goose Lakes, bathymetric and sediment profile maps are included in Appendix D. The maps show the location of the all transects along with their associated bathymetric and sediment profiles.

Along each transect, the maximum sediment depth and the lake depth corresponding to the maximum depth of sediment are shown Table 2.2. The above information was determined from the bathymetric and sediment profile maps in Appendix D. In Table 2.2, the term "variable" simply means that the maximum sediment depth did not occur at one particular lake depth, but over a wide range of lake depths along the transect.

In general, Goose Lake accumulated greater amounts of unconsolidated sediments than in Loon Lake as shown in Table 2.2. In Goose Lake, the greatest amount of sedimentation occurred in the vicinity of the lake's outlet along transects 1 and 2. The maximum sediment thickness along transects 1 and 2 were 8.0 and 10.0 feet thick, respectively. For Loon Lake, transect 2 recorded the highest degree of sedimentation, which was approximately 7.0 feet thick.

In addition to sediment profile comparisons, the bathymetry transects (Appendix D) were compared to bathymetric maps developed cooperatively by the Indiana Department of Natural Resources (IDNR) and the United States Geological Survey (USGS) in 1950's. In general, lake depth profiles recorded in 1990 as part of this study agreed reasonably well with IDNR/USGS bathymetric maps.

Table 2.2
Bathymetric and Sediment Profile Summary for Ten Indiana Lakes

Lake	Transect Number	Maximum Depth of Sediment (feet)	Depth of Lake Above the Maximum Sediment Depth (feet)
Loon Lake	1	4.0	50.0
	2	7.0	16.0
	3	3.5	40.0
	4	4.0	20.0
	5	2.5	42.0
Goose Lake	1	8.0	> 50.0
	2	10.0	12.0
	3	5.0	10.0 to 14.0
	4	6.0	10.0 to 16.0
	5	4.0	variable

Note: > denotes greater than

2.4 Watershed Characteristics

The drainage basin for Loon Lake has an area of 6,246 acres, and includes the 922 acre Goose Lake watershed and 84 acre Goose Lake. The drainage basin lies entirely within the Northern Lakes Natural Region of Indiana (Homoya, 1985). This area is part of the Eastern Lake section of the Central Lowland physiographic province and is characterized by maturely dissected and glaciated ridges and lowlands, moraines, lakes, and lacustrine plains. Watershed boundaries and the locations of major tributaries are shown in Figure 2.1.

Approximately 30 percent of the Loon Lake watershed is drained by Friskney Ditch. An estimated 30 percent of the Loon Lake watershed is drained by Winters Ditch. Approximately 32 percent of the Loon Lake watershed is drained by Old Lake Ditch. The balance of the watershed is drained by small ditches, tile drains and direct runoff.

Approximately 55 percent of the Goose Lake watershed is drained by the major inlet. The balance of the watershed is drained by smaller ditches, tile drains and direct runoff.

2.4.1 Topography

The landscape within the Loon and Goose Lakes watershed is one of rolling to steep hills on moraines and of deep depressions between the moraines (Ruesch, 1990).

The maximum elevation in the watershed is 990 feet MSL (mean sea level) at the west edge of Thorncreek Township and ranges down to 900 feet MSL at the outlet of Loon Lake.

2.4.2 Geology

Parent materials for soils in the Loon and Goose Lakes watershed are unconsolidated surficial geologic deposits resulting from glacial activity in Whitley and Noble Counties 10,000 years ago. The thickness of unconsolidated deposits ranges between 250 and 350 feet throughout the watershed (Gray, 1983). There are sharp differences in the properties of parent material, sometimes within short distances, because of the way glaciers deposited the material. The dominant parent materials in this area are loamy glacial till, sandy and gravelly outwash deposits, lacustrine deposits, and organic material. Glacial till is a mixture of coarse materials laid down by glaciers with a minimum of water action. Outwash deposits are size-sorted sand and gravel layers which have settled out of glacial meltwater. Lacustrine deposits are fine-grained layers which settled under still water. Organic material is deposited plant material which becomes muck (Ruesch, 1990, Hillis, 1980, McCarter, 1977).

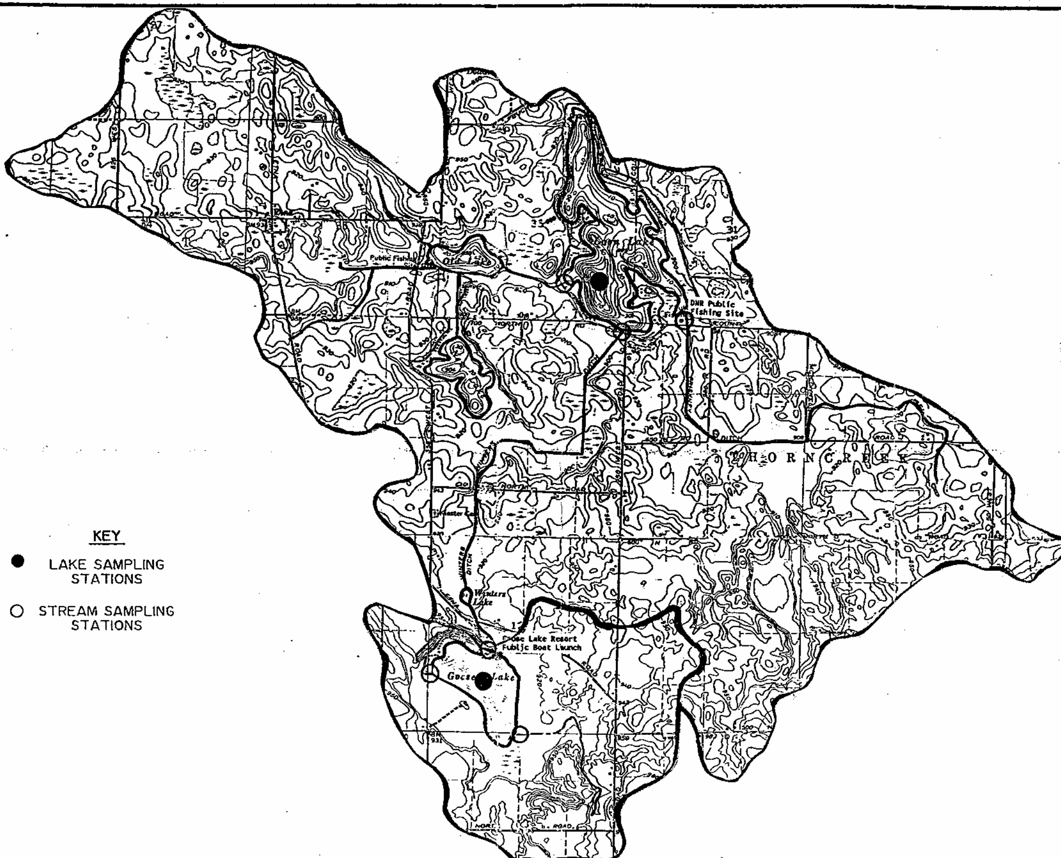

FIGURE 2.1

LOON & GOOSE LAKES WATERSHED

Antrim Shale of the Devonian period makes up the underlying bedrock in the Loon and Goose Lakes watershed. Antrim Shale is made up of black shale and gray shale with limestone in the lower part. Bedrock is older in the southern part of the watershed and younger in the north.

2.4.3 Soils

The soils in the Loon and Goose Lakes watershed are primarily formed in glacial till and loamy outwash over glacial till, on till plains and moraines. The dominant soil association in the watershed is the Morley-Rawson association, characterized by nearly level to steep, well drained and moderately well drained soils. The major soils in this association are used for cultivated crops, such as corn, soybeans, wheat, alfalfa, and red clover. The major soils are also well suited to woodlots which can produce excellent hardwood timber. The very poorly drained minor soils support the growth of water-tolerant trees and other wetland vegetation, suitable for wildlife habitat (Ruesch, 1990).

Erosion is a hazard on sloping and steep areas in most of the dominant till soils. Most of the soils in this association are severely limited for use as septic tank absorption fields because of wetness, slow permeability, or slope (Ruesch, 1990). A more detailed discussion of soil characteristics will be included in the pollutant budget section of this report.

As seen in the AGNPS (Agricultural Nonpoint Source) modeling results (Appendix E), large portions of the Loon and Goose Lakes watershed area contain soils which are highly erodible. In the Loon Lake and Goose Lake subwatershed areas, approximately 82 and 78 percent of the soils are classified as highly erodible. For these subwatershed areas, highly erodible soils were classified as having a soil erodibility factor (k) greater than 0.21.

2.4.4 Groundwater

Aquifers beneath the Loon and Goose Lakes watershed are primarily in deposits of sand and gravel. The average depth of these wells is between 75 and 100 feet below land surface datum with high water levels between 7 and 30 feet below the surface (Glatfelter et al., 1988 and Ruesch, 1990). The water is hard (200 to 300 milligrams per liter as calcium carbonate) with a fairly high iron content of 0.4 to 0.7 milligrams per liter (Glatfelter et al., 1988). These characteristics result in scale formation on heating utensils, greater soap requirements for cleaning, and reddish discoloration; however no adverse health effects would be expected from these levels of hardness or iron.

2.4.5 Land Use

Land use in the Loon and Goose Lakes watershed is primarily agricultural. As shown in Table 2.3, agriculture accounts for nearly 80 percent of the total land use in both watersheds. The next largest land use is woodlands in the Loon Lake watershed (14 percent) and wetlands in the Goose Lake watershed (16 percent).

Table 2.3
Land Use in the Loon and Goose Lake Watersheds

Land Use	Loon Lake†		Goose Lake	
	Acres	Percent	Acres	Percent
Agriculture	4100.1	78.2	733.0	79.5
Homes/Urban	116.7	2.2	14.2	1.5
Waterbodies	76.9	1.5	0.0	0.0
Wetlands	233.4	4.5	143.8	15.6
Woodlands	713.1	13.6	31.3	3.4
Lake	222.0	0.0	84.0	0.0
Watershed Area*	5240.2	100.0	922.3	100.0

† Loon Lake watershed areas do not include the Goose Lake subwatershed
* Watershed area does not include lake surface area

2.5 Population and Socio-Economic Structure

Goose and Loon Lakes provide recreational opportunities for residents of Whitley and Noble Counties (combined population approximately 65,000) and other area residents. Public access is readily available through the IDNR public access site at Loon Lake and the boat ramp at Goose Lake Resort.

Whitley and Noble Counties are rural in nature with little overall change in land use. The population growth rate is increasing between seven and eleven percent per decade in Whitley County. Occupations of permanent residents within the watershed are primarily associated with agriculture. Some residents are employed by industries in nearby towns.

The only town in the watershed is the small town of Etna, with a population of about 75 people, located one and on-half miles west of Loon Lake. Columbia City, the Whitley county seat, has a population of 5,686 (1990 projection) and is located about 6 miles southeast of Goose Lake.

2.6 History

Early inhabitants of northern Indiana were the Potawatomi Indians ("People of Fire"), an Algonquin linguistic family closely associated with the Chippewa and Ottawa. In the late 1700's, the Prairie Potawatomi moved into lower Michigan and northern Indiana while the Forest Potawatomi remained in the forests of northern Wisconsin and upper Michigan. Forests, swamps, and lakes in the area provided plentiful supplies of fish, game, herbs, roots, and seeds (Wolfe, 1989). The first white settlers arrived in the area in the 1820's and 30's. In 1838, the United States government organized a volunteer militia to force-march the Potawatomi Indians from northern Indiana to the valley of the Osage River in Kansas. The first Amish people arrived in the area in the early 1840's from Somerset County, Pennsylvania.

3.0 Lake Water Quality

3.1 Monitoring Program

In order to assess the water quality of Loon and Goose Lakes, water samples were collected from the epilimnion and hypolimnion on August 18, 1990. In accordance with the procedures established by the Indiana Lake Enhancement Program, samples were collected at the deepest part of the lakes during the summer stratification period. Water quality samples were analyzed for all parameters included in the Indiana Department of Environmental Management (IDEM) Eutrophication Index and some general water quality parameters as shown in Table 3.1.

Table 3.1
Parameters Analyzed in Lake Water Samples

Soluble orthophosphorus	Alkalinity
Total phosphorus	Secchi depth
Nitrate + nitrite nitrogen	Light intensity
Ammonia nitrogen	Dissolved oxygen
Total Kjeldahl nitrogen	Temperature
Total suspended solids	Phytoplankton
Conductivity	Chlorophyll a
pH	

For each lake, secchi depth and light intensity were measured. Dissolved oxygen and temperature profiles were recorded. Water samples from the photic zone were collected for the analysis of chlorophyll a for the determination of algal biomass. Two five-foot algal tows were conducted at each sampling station, one from the five foot level to the lake's surface and one through the thermocline, for the determination of phytoplankton species (to genera).

The above data are typical of those used by the Indiana Department of Environmental Management for their lake classification studies and also includes additional information required by the U.S. EPA for diagnostic/feasibility studies. This data has been shown to be sufficient to provide the necessary information to evaluate most lakes. The data has provided information on lake stratification, oxygen regime, water transparency, nutrients, general water chemistry, and lake trophic state. Trophic state indices for each lake were calculated using both IDEM procedures and the Carlson (1977) trophic state index.

Secchi depth was determined using an 8 inch (20 cm) black-white Secchi disk. Light intensity was measured using a Licor photometer. Water samples were collected using a horizontal alpha water sampler. Dissolved oxygen and temperature profile were measured using a YSI dissolved oxygen/temperature meter. Phytoplankton samples were collected using a "birge style" closing net with a 80μm net mesh size and a mouth diameter of 5 inches (13 cm).

Samples for phytoplankton analyses were preserved in the field with 7.0 mL of Lugol's solution per liter. Another 3 mL of Lugol's solution was added before storage in a refrigerator. Algal cells were identified and counted using a Sedgewick-Rafter counting chamber and a microscope equipped with a Whipple grid.

3.2 Quality Assurance/Quality Control Procedures

3.2.1 Introduction

A quality control program was performed in order to insure that the equipment and procedures used in this study produced results that are both precise and accurate. Precision was monitored by performing duplicate analyses on selected samples. Accuracy was monitored by analyzing spike samples and special quality control samples having known concentrations of various parameters.

All laboratory procedures were performed in accordance with *Standard Methods for the Examination of Water and Wastewater*, 17th Edition; *Methods for Chemical Analysis of Water and Wastes* (EPA-600/4-79-020); and *Handbook for Analytical Quality Control in Water and Wastewater Laboratories* (EPA-600/4-79-019). Results of the quality control program were recorded and were reviewed and evaluated.

The quality control/quality assurance procedures used in this study are as follows: (1) equipment calibration in accordance to manufacturer's recommendations, (2) standardization curves for all forms of nitrogen and phosphorus, (3) control charts established for all forms of phosphorus and nitrate/nitrate standards, (4) spiked sample analysis, (5) EPA reference samples analysis, (6) duplicate sample analysis, and (7) field split sample analysis.

3.2.2 Parameters and Procedures

The following is a list of parameters and the procedures used for each:

Parameter	Procedure
pH	Standard Methods 4500-H^+ B
Alkalinity	EPA 310.1
Dissolved Oxygen	Standard Methods 4500-O C
Total Phosphorus	Standard Methods 4500-P B,E
Soluble Orthophosphorus	Standard Methods 4500-P, B,E
Total Kjeldahl Nitrogen	Standard Methods 4500-N_{org} C
Nitrate/Nitrite	Standard Methods 4500-NO_3 F
Ammonia	Standard Methods 4500-NH_3 F
Total Suspended Solids	Standard Methods 2540 D
Chlorophyll a	Standard Methods 10200H-2
Conductivity	Standard Methods 2510 B

Samples were collected and analyzed by F. X. Browne Associates, Inc. The sampling efforts were coordinated with the Loon Lake Property Owners Association and the Goose Lake Association, who assisted F. X. Browne Associates, Inc. personnel in sample collection.

3.3 Chemical and Biological Interactions

Existing water quality in a lake is determined by numerous chemical, physical, and biological factors. The amount of nutrients and sediments delivered to a lake via its tributaries is a major factor affecting water quality. Variations in ambient temperature and sunlight are also important factors. Physical, chemical, and biological characteristics of Loon and Goose Lakes are discussed in the following sections.

3.4 Lake Water Quality Data

3.4.1 Temperature and Dissolved Oxygen

Usually at the beginning of summer, temperate lakes develop stratified layers of water. Warmer waters are near the lake's surface (epilimnion) and colder waters are near the lake's bottom (hypolimnion). As temperature differences become greater between these two water layers, the resistance to mixing will also increase. Under these circumstances, the epilimnion is usually oxygen rich due to photosynthesis and direct inputs from the atmosphere, while the hypolimnion may become depleted of oxygen due to the decomposition of organic matter and isolation from oxygen sources (surface waters and the atmosphere).

Loon Lake

As shown in Figure 3.1, Loon Lake was well stratified in August of 1990. Temperatures ranged from 78.8° Fahrenheit (26.0° Celsius) at the lake's surface to 43.2° Fahrenheit (6.2° Celsius) near the lake bottom. Dissolved oxygen concentration at the lake's surface was 11.2 mg/L. Below a depth of 13 feet (4 m), the dissolved oxygen concentrations were less than 1 mg/L. In general, dissolved oxygen levels below 4 mg/L may impair some forms of aquatic life. Extremely low dissolved oxygen conditions promote the dissolution of phosphorus bound in lake sediments, providing nutrients for algal growth.

Goose Lake

As shown in Figure 3.2, Goose Lake was well stratified in August of 1990. Temperatures ranged from 80.6° Fahrenheit (27.0° Celsius) at the lake's surface to 44.6° Fahrenheit (7.0° Celsius) near the lake bottom. Dissolved oxygen concentration at the lake's surface was 10.0 mg/L. Below a depth of 13 feet (4 m), the dissolved oxygen concentrations were less than 1 mg/L. Dissolved oxygen levels below 4 mg/L may impair some forms of aquatic life. Extremely low dissolved oxygen conditions promote the dissolution of phosphorus bound in lake sediments, providing nutrients for algal growth.

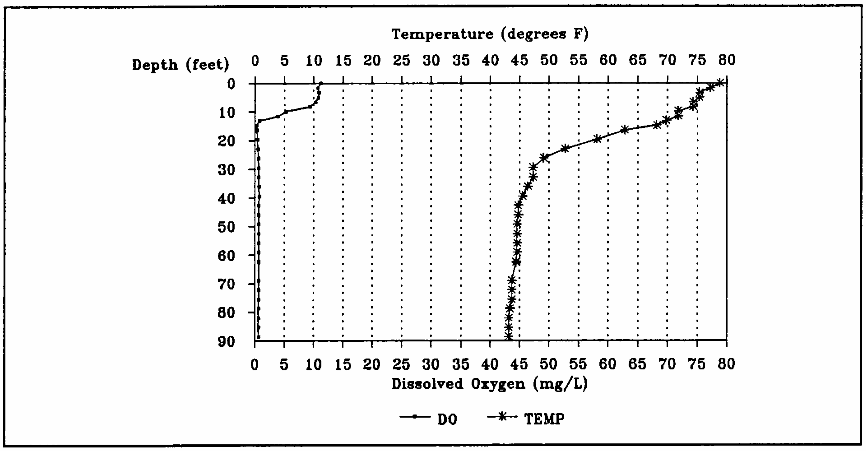

Figure 3.1 Temperature and Dissolved Oxygen Profiles at Loon Lake

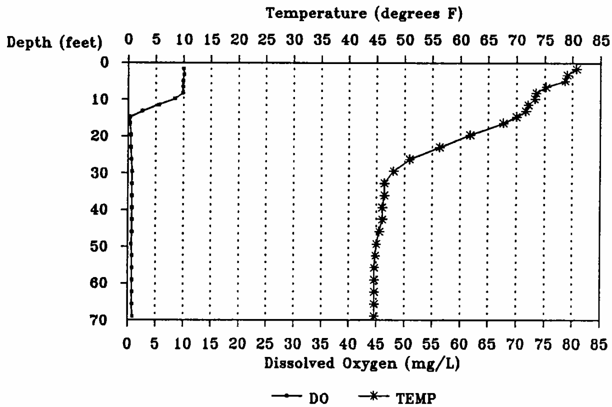

Figure 3.2 Temperature and Dissolved Oxygen Profiles at Goose Lake

3.4.2 Alkalinity, pH and Conductivity

Alkalinity and pH are interrelated. pH is a term used to express the intensity of the acids or bases in the water in terms of hydrogen ion concentration. It is important because most chemical and biological reactions are controlled or affected by pH. The alkalinity of water is a measure of the buffering capacity, or the capacity of the water to neutralize acids. Alkalinity of neutral waters is due primarily to salts of weak acids such as bicarbonates, carbonates, borates, silicates and phosphates. Although many materials contribute to the alkalinity of water, most of the alkalinity in natural waters is caused by hydroxides, carbonates and bicarbonates. The bicarbonates represent the major form of alkalinity because they are formed by the action of carbon dioxide with basic materials in soil.

In lake ecosystems, interactions between hydrogen ions and buffering ions occur when phytoplankton use carbon dioxide in their photosynthetic activity. As carbon dioxide is removed by algae, the pH of the water increases, thereby transforming both carbonate and bicarbonate forms of alkalinity into carbon dioxide, which is used by algae for further growth. Therefore, carbonate indirectly acts as a food source for the algae.

Conductivity refers to the ability of a water sample to conduct an electric current. Conductivity is directly related to the ionic species present in solution, which include both alkalinity and pH. Conductivity values vary greatly for both surface and groundwater, where values range from 50 to 1500 micromhos/cm (Standard Methods, 1989).

Loon Lake

As shown in Table 3.2, the lowest alkalinity and highest pH values were recorded at the epilimnion and these levels are probably attributed to photosynthetic activity by phytoplankton. Typical lake pH values range from 6 to 9. Alkalinities for both the hypolimnion and the epilimnion may be classified as moderate, thereby providing a sufficient buffering capacity with regard to acidic inputs (i.e. acid rain). The conductivities for both the epilimnion and hypolimnion are shown in Table 3.2. The values fall within the typical range for potable waters.

Table 3.2
Alkalinity, pH and Conductivity at Loon Lake

Parameter	Concentration in Epilimnion	Concentration in Hypolimnion
Alkalinity, total (mg/L as $CaCO_3$)	136	160
pH (standard units)	8.5	7.6
Conductivity (micromhos)	387	463

Goose Lake

As shown in Table 3.3, the lowest alkalinity and highest pH values were recorded at the epilimnion and these levels are probably attributed to algal uptake of carbon dioxide for photosynthesis. pH values at Goose Lake fall within the range of values reported for surface water systems. Alkalinities for both the hypolimnion and the epilimnion may be classified as moderate, thereby providing a sufficient buffering capacity with regard to acidic inputs (i.e. acid rain). Conductivities values are similar to Loon Lake and these values are typical for potable water sources.

Table 3.3
Alkalinity, pH and Conductivity at Goose Lake

	Epilimnion	Hypolimnion
Alkalinity, total (mg/L as $CaCO_3$)	106	152
pH (standard units)	8.9	7.4
Conductivity (micromhos)	315	406

3.4.3 Transparency, Total Suspended Solids, Chlorophyll a, and Phytoplankton

The transparency, or clarity, of water is most often reported in lakes as the Secchi depth. This measurement is taken by lowering a circular white or black-and-white disk, approximately 8 inches in diameter, into the water until it is no longer visible. Observed Secchi depths range from an inch in very turbid lakes to over 130 feet in the clearest known lakes (Wetzel, 1975). Therefore, greater Secchi depths represent better water transparency. Although somewhat simplistic and subjective, this testing method probably best represents the conditions which are most readily visible to the common lake user.

Total suspended solids is a measure of the amount of particulate matter in the water column. Suspended solids are comprised of both organic matter, such as algae, and inorganic material, including soil particles and clay minerals. Therefore, total suspended solids concentrations are directly related to transparency.

Chlorophyll a is a pigment which gives the green color to all green plants. Its function is to convert sunlight to chemical energy in the process known as photosynthesis. Water samples containing algae can be treated to extract chlorophyll a from algal cells for analysis. Chlorophyll a constitutes about 1 to 2 percent of the dry weight of planktonic algae, so the amount of chlorophyll a in a water sample is an indicator of phytoplankton biomass.

Phytoplankton are microscopic algae which have little or no resistance to currents and live free-floating and suspended in open water. Forms may be unicellular, colonial or filamentous. As photosynthetic organisms (primary producers), they form the base of aquatic food chains and are grazed upon by zooplankton and herbivorous fish.

A healthy lake should support a diverse assemblage of phytoplankton, in which many algal classes are represented. Excessive growth of a few species is usually undesirable. Such growths can cause oxygen depletion in the water at night, when the algae are respiring but not photosynthesizing. Oxygen depletion can also occur after an algal bloom when bacteria, using dead algal cells as a food source, grow and multiply.

Loon Lake

For Loon Lake, transparency, total suspended solids, chlorophyll a and phytoplankton data are shown in Table 3.4. The highest phytoplankton count and total suspended solids concentration was noted in the epilimnion, contributing to the low transparency of the lake. The relatively high chlorophyll a level for Loon Lake corresponded to the high phytoplankton count recorded at the epilimnion.

Table 3.4
Transparency, Total Suspended Solids, Chlorophyll a and Phytoplankton at Loon Lake

Parameter	Result
Transparency in feet (meters)	2.9 (0.9 m)
Total Suspended Solids (mg/L)	6.7 (epilimnion) 1.2 (hypolimnion)
Chlorophyll a (μg/L)	8.7
Phytoplankton (cells/L)	3,351,000 (0 - 5 ft tow) 365,000 (5 ft tow through thermocline)

Blue green algae (Cyanophyceae) represented 99 and 97% of the planktonic populations in the epilimnion and thermocline samples, respectively. The following is the list of the blue-green algae identified at Loon Lake:

Epilimnion - *Lyngbya*, *Anabaena*, *Aphanizomenon* and *Microcystis*
Thermocline - *Microcystis* and *Anabaena*

Complete phytoplankton results are presented in Appendix C. Excessive growths of some species of algae, particularly members of the blue-green group, may cause taste and odor problems, release toxic substances to the water, or give the water an unattractive green soupy or scummy appearance. Dominance by bluegreen algae is associates with lakes receiving elevated levels of nutrients, particularly phosphorus.

Goose Lake

For Goose Lake, transparency, total suspended solids, chlorophyll a and phytoplankton data are shown in Table 3.5. The highest phytoplankton count was observed in the epilimnion, contributing to the low transparency of the lake. The relatively high chlorophyll a level for Goose Lake corresponded to the high phytoplankton count recorded at the epilimnion.

The highest total suspended solids concentration was recorded at the hypolimnion even though the epilimnion accounted for higher phytoplankton populations. One possible explanation for this high hypolimnetic total suspended solids concentration is that the inflow from tributaries is cooler and denser than the receiving lake water. In this case, the inflow would travel along the lake's bottom and if the inflow was laden with sediment, high total suspended solids concentrations would be observed in the hypolimnion. During our bathymetric survey, a plume of suspended material was detected in the hypolimnion by our fathometer. This plume was located along a line between the northwest tile inlet and the lake outlet.

Table 3.5 Transparency, Total Suspended Solids, Chlorophyll a and Phytoplankton at Goose Lake

Parameter	Result
Transparency in feet (meters)	5.2 (1.6 m)
Total Suspended Solids (mg/L)	0.85 (epilimnion) 2.2 (hypolimnion)
Chlorophyll a (μg/L)	7.6
Phytoplankton (cells/L)	2,135,000 (0 - 5 ft tow) 986,000 (5 ft tow through thermocline)

Blue green algae (Cyanophyceae) represented 100% of the planktonic populations in both samples. The following is the list of the dominant blue-green algae identified at Goose Lake:

Epilimnion - *Anabaena*, *Lyngbya*, *Aphanizomenon* and *Microcystis*
Thermocline - *Lyngbya*, *Anabaena*, *Aphanizomenon* and *Microcystis*

Complete phytoplankton results are presented in Appendix C. Excessive growths of some species of algae, particularly members of the blue-green group, may cause taste and odor problems, release toxic substances to the water, or give the water an unattractive green soupy or scummy appearance. Dominance by bluegreen algae is associates with lakes receiving elevated levels of nutrients, particularly phosphorus.

3.4.4 Nutrient Concentrations

Phosphorus and nitrogen compounds are important for the growth of algae and other aquatic organisms in the aquatic food web. Both total phosphorus and dissolved orthophosphorus were analyzed at Loon Lake and Goose Lake. Total phosphorus represents the sum of all phosphorus including inorganic phosphorus, live algae, dead algae, other microorganisms, organic phosphorus, polyphosphates and orthophosphates. Dissolved orthophosphate is the phosphorus form that is most readily available for algal uptake. Total Kjeldahl nitrogen and nitrate plus nitrite nitrogen were also analyzed at Loon and Goose Lakes. Total Kjeldahl nitrogen is the sum of organic nitrogen and ammonia. In aquatic ecosystems, ammonia and nitrate are the most available forms for algae and other aquatic organisms.

In general, limited amounts of algae are desirable in lake ecosystems. Algal growth depends on a variety of nutrients, including macronutrients such as phosphorus, nitrogen, and carbon, and trace nutrients, such as iron, manganese, and other trace minerals. The Law of the Minimum states that biological growth is limited by the substance that is present in the minimum quantity with respect to the needs of the organism. Nitrogen and phosphorus are usually the nutrients that limit growth in most natural waters. If the limiting nutrient can be controlled, water quality improvements can be expected.

Depending on the species, algae require approximately 15 to 26 atoms of nitrogen for every atom of phosphorus. This ratio converts to 7 to 12 milligrams of nitrogen per 1 milligram of phosphorus on a mass basis. Therefore, a ratio of total nitrogen to total phosphorus (TN:TP) of 15:1 is generally regarded as the dividing point between nitrogen and phosphorus limitation (U.S. EPA, 1980). Identification of the limiting nutrient becomes more certain as the total nitrogen to total phosphorus ratio moves farther away from the dividing point, with ratios of 10:1 or less providing a strong indication of nitrogen limitation and ratios of 20:1 or more strongly indicating phosphorus limitation (Porcella et al., 1974).

Loon Lake

Results of the nutrient analyses are shown in Table 3.6. The total phosphorus concentrations in the epilimnion and the hypolimnion were 0.03 and 0.27 mg/L, respectively. Orthophosphate were much lower in the epilimnion than the hypolimnion, which may be attributed to high algal uptake in the epilimnion. Total Kjeldahl nitrogen concentrations were greater than nitrate plus nitrite concentrations (total oxygenized nitrogen), indicating that nitrogen was dominated by organic forms.

Table 3.6
Nutrient Concentrations for Loon Lake

Parameter	Concentration in Epilimnion	Concentration in Hypolimnion
Total Phosphorus (mg/L)	0.030	0.27
Orthophosphorus (mg/L)	<0.01	0.17
Total Kjeldahl Nitrogen (mg/L)	1.17	1.86
Ammonia (mg/L)	N/A	N/A
Nitrate & Nitrite (mg/L)	0.23	0.70

Note: N/A, not analyzed due to sample volume loss.

The TN:TP ratio was calculated for the epilimnion of Loon Lake, where TN is equal to TKN and TON. The TN:TP ratio was 46.6, indicating that phosphorus is the limiting nutrient for this lake system.

Goose Lake

Results of the nutrient analyses are shown in Table 3.7. The total phosphorus concentrations in the epilimnion and the hypolimnion were 0.025 and 0.32 mg/L, respectively. Orthophosphate were much lower in the epilimnion than the hypolimnion, which may be attributed to high algal uptake in the epilimnion. Total Kjeldahl nitrogen concentrations were greater than nitrate plus nitrite concentrations (total oxygenized nitrogen), therefore nitrogen was dominated by organic forms.

Table 3.7
Nutrient Concentrations for Goose Lake

Parameter	Concentration in Epilimnion	Concentration in Hypolimnion
Total Phosphorus (mg/L)	0.025	0.32
Orthophosphorus (mg/L)	<0.01	0.27
Total Kjeldahl Nitrogen (mg/L)	1.17	1.95
Ammonia (mg/L)	N/A	N/A
Nitrate & Nitrite (mg/L)	<0.01	0.03

Note: N/A, not analyzed due to loss of sample volume.

The TN:TP ratio was calculated for the epilimnion of Goose Lake, where TN is equal to TKN and TON. The TN:TP ratio was 48.8, which indicates that phosphorus is the limiting nutrient for this lake system.

3.4.5 Macrophytes

Loon Lake

A macrophyte (aquatic plant) survey was conducted at Loon Lake. The survey consisted of macrophyte identification and delineation. Macrophytes are defined as aquatic plants ranging from completely submerged stands of algae to stands of rooted plants with floating leaves. A detailed macrophyte distribution map is attached in Appendix D. Table 3.8 contains a list of species identified in Loon Lake. Macrophyte distribution at Loon Lake was characterized by dense stands of floating and submerged plants along the southern shore of the lake, comprised of waterlilies, coontail, milfoil and pondweeds. These dense stands were interspersed with groups of tapegrass and waterlilies. A dense cattail stand was located at the public access site. The remaining shoreline contained groups of waterlilies or tapegrasses.

Table 3.8
List of Macrophyte Species Identified in Loon Lake

Category	Common Name	Scientific Name
Emergents		
	cattail	*Typha*
	arrow arum	*Peltandra*
	rushes	*Juncus spp.*
	sedges	*Scirpus validus*
	purple loosestrife	*Lythrum salicaria*
	smartweed	*Polygonum*
Floating Leaved		
	white water lily	*Nympheae*
	yellow water lily	*Nuphar*
Submerged		
	tapegrass	*Vallesnaria*
	milfoil	*Myriophyllum*
	bushy pondweed	*Najas*
	bassweed	*Potamogeton amplifolius*
	muskgrass	*Chara*
	coontail	*Ceratophyllum*

Goose Lake

A macrophyte (aquatic plant) survey was conducted at Goose Lake. The survey consisted of macrophyte identification and delineation. Macrophytes are defined as aquatic plants ranging from completely submerged stands of algae to stands of rooted plants with floating leaves. A detailed macrophyte distribution map is attached in Appendix D. Table 3.9 contains a list of species identified in Goose Lake. Macrophyte distribution at Goose Lake was characterized by dense stands of plants around the entire shore, except where chemical or mechanical control measures were used.

Large assemblages of floating leaved mixed emergent macrophytes alternated with almost pure stands of floating leaved macrophytes. Macrophytes were dense along the shore to a depth of approximately five feet.

Table 3.9
List of Macrophyte Species Identified in Goose Lake

Category	Common Name	Scientific Name
Emergents		
	cattail	*Typha*
	arrow arum	*Peltandra*
	rushes	*Juncus spp.*
	sedges	*Scirpus validus*
	purple loosestrife	*Lythrum salicaria*
	arrowhead	*Sagittaria*
	pickerelweed	*Pontederia cordata*
Floating Leaved		
	white water lily	*Nympheae*
	yellow water lily	*Nuphar*
Submerged		
	milfoil	*Myriophyllum*
	coontail	*Ceratophyllum*

3.4.6 Sediment Analyses

Using a Ekman dredge, sediment samples were collected from each lake on August 28, 1990. The sediment sample locations are shown in Figure 2.1. Each sample was analyzed for particle size distribution, percent total solids, percent volatile solids, total phosphorus, and total nitrogen. The above sediment analyses from Loon and Goose Lakes are presented in Tables 3.10 and 3.11.

In Table 3.10, the particle size distribution of lake sediments in Loon and Goose Lakes are shown. For both lakes, accumulated sediments are primarily composed of silt. The silt fractions were 95.4 and 98.0 percent of the sediment samples collected from Loon Lake and Goose Lakes, respectively.

Table 3.10
Particle Size Distribution Within the Sediments of Loon and Goose Lakes

Lake	Fine Sand (percent)	Silt (percent)	Clay (percent)	Colloids (percent)
Loon Lake	4.6	95.4	<0.1	<0.1
Goose Lake	2.0	98.0	<0.1	<0.1

For Loon and Goose Lakes, the percent total solids, percent volatile solids, total phosphorus concentration, and total nitrogen concentration of collected sediment samples are presented in Table 3.11. The percent total solids is the amount of solids remaining after all water is evaporated from a sediment sample. For Loon and Goose Lakes sediment samples, the percent total solids were 23.77 and 23.11 percent, respectively. In general, lake sediments generally contain about 25 to 50 percent total solids.

Table 3.11
Concentrations of Solids and Nutrients in the Sediments in Loon and Goose Lakes

Lake	Total Solids (percent)	Volatile Solids (percent)	Total Phosphorus (mg/kg)	Total Nitrogen (mg/kg)
Loon Lake	23.77	11.47	630	18.6
Goose Lake	23.11	11.31	557	20.9

Total solids are the composed of volatile (organic) and inorganic solids. After exposing a sediment sample in a muffle furnace, the remaining material is known as the inorganic solids fraction. Therefore, the difference between the total solid and the inorganic solid fractions is the volatile or organic solids fraction. For Loon and Goose Lakes, the sediment samples contain nearly equal fractions of inorganic and organic solids as shown in Table 3.11.

The total phosphorus and total nitrogen concentrations in sediment samples from Loon and Goose Lakes are shown in Table 3.11. The total phosphorus and total nitrogen concentrations in these sediment samples are comparable to other lakes in the region (F. X. Browne Associates, Inc., 1991).

Based on guidelines published by IDEM, the maximum background concentration for total phosphorus and total Kjeldahl nitrogen are 610 and 1,500 mg/Kg. Only the sediment sample from Loon Lake exceeds the maximum background concentration for phosphorus. The Loon Lake sediment sample is below the "low concern" level for phosphorus. The "low concern" level is defined as 2 to 10 times greater than the maximum background concentration. For both lakes, the sediment samples concentrations of total nitrogen were far less than the maximum background concentration for total Kjeldahl nitrogen (remembering that total nitrogen is the sum of total Kjeldahl nitrogen and nitrate plus nitrite nitrogen). Total nitrogen concentrations were compared to IDEM's maximum background concentration for total Kjeldahl nitrogen since these lake sediment samples were not analyzed for total Kjeldahl nitrogen.

3.5 Lake Trophic State

The trophic status of Goose and Loon Lakes in Indiana were determined using the Indiana Department of Environmental Management Eutrophic Index (IDEM EI), Carlson's Trophic State Index (TSI) (Carlson, 1977) and criterion set forth by the United States Environmental Protection Agency (U.S. EPA, 1980).

3.5.1 IDEM Trophic Index

Based on the criterion as set forth by the Indiana Department of Environmental Management (IDEM), the trophic status of Loon lake was determined using the IDEM Eutrophic Index (EI). The IDEM EI, which is a trophic continuum ranging from 0 to 75, assigns eutrophy points for a variety of parameters.

The sum of eutrophy points for these parameters is the IDEM Eutrophic Index for a given lake. According the IDEM, lakes are classified as listed below.

Class I - highest quality, least eutrophic lakes (0 - 25)
Class II - intermediate quality, intermediate eutrophic lakes (26 - 50)
Class III - lowest quality, advanced eutrophic lakes (51 - 75)
Class IV - remnant natural lakes and oxbow lakes

Loon Lake

As shown in Table 3.12, the IDEM Eutrophic Index value for Loon Lakes was 53-56. Based upon the IDEM criteria, Loon Lake would be categorized as a Class III lake system. It should be noted that ammonia concentrations could not be analyzed due to a loss of sample volume, therefore no data was available for organic and ammonia nitrogen. As a result, a range of IDEM Eutrophic Index values for Loon Lake was determined by assuming the following three scenarios: total Kjeldahl nitrogen was composed entirely organic nitrogen, total Kjeldahl nitrogen was composed entirely of ammonia nitrogen, and total Kjeldahl nitrogen was composed of both ammonia and organic nitrogen in a combination that gave the highest point total.

The above range of values is higher than the IDEM Index values reported for 1974 and 1988. In 1974, Loon Lake scored 46 eutrophy points (Pearson, 1989) and scored 33 eutrophy points in 1988 (IDEM, 1992).

Goose Lake

As shown in Table 3.13, the IDEM Eutrophic Index value for Goose Lake was 49-52. Based upon the IDEM criteria, Goose Lake would be categorized as Class II/Class III lake system. It should be noted that ammonia concentrations could not be analyzed due to a loss of sample volume, therefore no data was available for organic and ammonia nitrogen. As a result, a range of IDEM Eutrophic Index values for Loon Lake was determined by assuming the following three scenarios: total Kjeldahl nitrogen was composed entirely organic nitrogen, total Kjeldahl nitrogen was composed entirely ammonia nitrogen, and total Kjeldahl nitrogen was composed of both ammonia and organic nitrogen in a combination that gave the highest point total.

The above range of values were determined from water quality data collected on August 18, 1990. This range of values is lower than the IDEM Index value reported in 1974, but is higher than the IDEM value reported for July 3, 1990. In 1974, Goose Lake scored 61 eutrophy points (Pearson, 1989) and only scored 40 eutrophy points on July 3, 1990 (IDEM, 1992).

Table 3.12
IDEM Eutrophic Index for Loon Lake

Parameter	Result and Points*
Total Phosphorus (mg/L as P)	0.15 (3)
Soluble Phosphorus (mg/L as P)	<0.088 (3)
Organic Nitrogen (mg/L as N)	--- (0-4)
Nitrate Nitrogen (mg/L as N)	0.46 (2)
Ammonia Nitrogen (mg/L as N)	--- (0-4)
% Dissolved Oxygen Saturation	126 (2)
% Water Column Containing Dissolved Oxygen	100 (0)
Light Penetration (m)	3.0 (6)
% Light Transmission (m)	13 (4)
Total Plankton (cells/L, 0-5 ft tow)	3,351,000 (10)
Blue-green Dominance	Yes (5)
Total Plankton (cells/L, 5 ft tow through thermocline)	365,000 (10)
Blue-green Dominance	Yes (5)
Population over 950,000	No (0)
IDEM Trophic Index	53 - 56†

*values in parentheses are the assigned ISBH Eutrophic Points
†IDEM Trophic Value range - no ammonia data was available, which also prevents calculation of organic nitrogen concentrations.

Table 3.13
IDEM Eutrophic Index for Goose Lake

Parameter	Result and Points*
Total Phosphorus (mg/L as P)	0.17 (3)
Soluble Phosphorus (mg/L as P)	0.14 (3)
Organic Nitrogen (mg/L as N)	--- (0-4)
Nitrate Nitrogen (mg/L as N)	0.02 (0)
Ammonia Nitrogen (mg/L as N)	--- (0-4)
% Dissolved Oxygen Saturation	116 (1)
% Water Column Containing Dissolved Oxygen	100 (0)
Light Penetration (m)	5.2 (0)
% Light Transmission	19 (4)
Total Plankton (cells/L, 0 - 5 ft tow)	2,135,000 (10)
Blue-green Dominance	Yes (5)
Total Plankton (cells/L, 5 ft tow through thermocline)	986,000 (10)
Blue-green Dominance	Yes (5)
Population over 950,000	Yes (5)
IDEM Trophic Index	49 - 52†

* values in parentheses are the assigned ISBH Eutrophic Points

† IDEM Trophic Value range - no ammonia data was available, which also prevents calculation of organic nitrogen concentrations.

3.5.2 Carlson Trophic State Index

In addition to the IDEM eutrophic index, trophic status was determined by using the Carlson's Trophic State Index (TSI). The Carlson Trophic State Index (TSI) is a trophic continuum ranging from 0 to 100. TSI values greater than 50 generally indicate eutrophic lake conditions. TSI values may be calculated for chlorophyll a concentrations, surface total phosphorus concentrations and Secchi disk transparency. For Loon and Goose Lakes, TSI values were based on one summer value for each parameter. Carlson's TSI is best calculated using summer averages for each parameter.

Loon Lake

As shown in Table 3.14, TSI values ranged from 51.8 to 61.5 for Loon Lake. Therefore, Loon Lake may be classified as eutrophic based on Carlson's Trophic State Index.

Table 3.14
Carlson's Trophic Indices for Loon Lake

Total Phosphorus	Chlorophyll a	Transparency
53.2	51.8	61.5

Goose Lake

As shown in Table 3.15, TSI values for Goose Lake ranged from 50.5 to 53.2. Therefore, Goose Lake may be classified as eutrophic based on Carlson's Trophic State Index.

Table 3.15
Carlson's Trophic Indices for Goose Lake

Total Phosphorus (μg/L)	Chlorophyll a (μg/L)	Transparency (m)
50.6	50.5	53.2

3.5.3 EPA Trophic Criteria

The United States Environmental Protection Agency (U.S. EPA) has set ranges for total phosphorus concentrations, chlorophyll a concentrations and Secchi disk transparency as indicators of lake trophic status. Table 3.16 compares the EPA trophic criteria to the Loon Lake and Goose Lake monitoring data.

Table 3.16
Comparison of Loon Lake and Goose Lake Monitoring Data to EPA Trophic State Criteria*

Characteristic	EPA Eutrophic Criterion	Loon Lake	Goose Lake
Summer Surface Total Phosphorus (μg/L)	> 20 - 30	30	25
Summer Chlorophyll a (μg/L)	≥ 6 - 10	8.7	7.6
Summer Secchi Disk Transparency (m)	≤ 1.5 - 2 (≤ 4.9 - 6.6 ft)	0.9 (3.0 feet)	1.6 (5.2 feet)

* Source: U.S. EPA 1980

Loon Lake

Loon Lake had high chlorophyll a and total phosphorus concentrations and low secchi disk transparencies. Based on the EPA criteria listed above, Loon Lake was classified as eutrophic.

Goose Lake

Goose Lake had high chlorophyll a and total phosphorus concentrations and low secchi disk transparencies. Based on the EPA criteria listed above, Goose Lake was classified as eutrophic.

3.6 Stream Water Quality

Inflowing tributaries and lake outlets were sampled during base flow (low flow) conditions on August 14, 1990, and during stormflow conditions on October 4, 1990. In Figure 2.1, the stream sampling sites (the outlets of Loon and Goose Lakes plus five inflowing tributaries) are shown. These stream sampling sites were used for both baseflow and stormflow conditions. For both study dates, samples were analyzed for total phosphorus, orthophosphorus, nitrate plus nitrite, ammonia, total Kjeldahl nitrogen, pH, alkalinity, conductivity, fecal coliform and fecal streptococcus.

It is important to remember that the stream samples represent a single "snapshot" of water quality in the stream at a particular time. Concentrations of water quality parameters in streams can fluctuate widely, depending on runoff and flow conditions, as well as land management activities upstream. For each of the streams, no streamflow measurements were recorded. The collection of streamflow data were beyond the scope of this study, therefore it is not possible to assess the actual stream loading of nutrients, sediments and bacteria to each of the lakes.

For the Loon and Goose Lakes watershed, stream water quality under both base flow and storm flow conditions is discussed in the following paragraphs. For a brief discussion of total phosphorus, orthophosphorus, nitrate plus nitrite, ammonia, total Kjeldahl nitrogen, pH, alkalinity, and conductivity, refer to Section 3.3, Water Quality Data.

In addition to the above water quality parameters, water samples were analyzed for fecal coliform and fecal streptococcus. Both fecal coliform and fecal streptococcus are groups of bacteria, which are indicators of fecal pollution from both human and other animal sources. Indicator groups of bacteria reflect the potential presence of pathogenic organisms (Thomann and Mueller, 1987). As the number of the above bacteria increase, the chance of encountering a pathogenic organism also increases. In general, testing procedures for "...pathogenic bacteria are difficult to perform and generally are not reproducible" (Hammer, 1986). Therefore, test procedures for nonpathogenic indicator bacteria is more desirable than for specific pathogenic organisms.

BaseFlow Conditions

In order to assess the water quality of streams under baseflow conditions, the Loon and Goose Lakes outlets plus five lake tributaries were sampled on August 14, 1990. All water samples were analyzed for total phosphorus, orthophosphorus, nitrate plus nitrite, ammonia, total Kjeldahl nitrogen, pH, alkalinity, conductivity, fecal coliform and fecal streptococcus. Stream flow water quality data for August 14, 1990, is presented in Tables 3.17 through 3.19.

In Table 3.17, pH, alkalinity, conductivity and total suspended solid concentrations are shown for seven streams. For these streams, the pH ranged from 7.2 to 8.4 standard units with a mean value of 7.9. For most surface waters, pH values typically fall within a range of 6 to 9 standard units. Alkalinity ranged from 108 to 188 mg/L as calcium carbonate with a mean concentration of 146 mg/L.

Conductivity ranged from 247 to 481 micromhos with a mean value of 360 micromhos. For both surface water and groundwater, conductivity values typically range from 50 to 1500 micromhos. For these streams, total suspended concentrations ranged from 0.2 to 73.0 mg/L with a mean value of 14.5 mg/L. The highest total suspended solids concentration was measured in the Southeast inlet to Goose Lake.

In Table 3.18, nitrate plus nitrite, ammonia, total Kjeldahl nitrogen, total phosphorus and orthophosphorus concentrations are shown for seven streams in the Loon and Goose Lakes watershed. Nitrate plus nitrate concentrations ranged from less than 0.01 to 0.92 mg/L as nitrogen with a mean concentrations of 0.30 mg/L. Ammonia nitrogen levels ranged from less than 0.10 to 0.15 mg/L as nitrogen with a mean concentration of less than 0.10 mg/L. Of the seven streams analyzed, six streams recorded values below the detection limit. Total Kjeldahl nitrogen concentrations ranged from 0.69 to 1.26 mg/L as nitrogen with a mean level of 0.97 mg/L.

For the seven streams that were sampled, total phosphorus concentrations ranged from below the detection limit of 0.01 to 0.52 mg/L as phosphorus with a mean value of 0.24 mg/L as phosphorus. The highest total phosphorus concentrations were recorded in Friskney Ditch and the Southeast inlet to Goose Lake. Orthophosphorus concentrations ranged from less than 0.01 to 0.35 mg/L as phosphorus. The mean orthophosphorus concentration was 0.09 mg/L as phosphorus and the highest orthophosphorus concentration were once again recorded in Friskney Ditch and the Southeast inlet to Goose Lake.

Fecal coliform and fecal streptococcus counts are shown in Table 3.19 for seven streams within the Loon and Goose Lakes watershed. Fecal coliform counts ranged from 60 to 282,000 cells/100 mL with a mean count of 52,576 cells/100 mL. Of all the streams, the southeast inlet of Goose Lake the highest fecal coliform count. Recently, the Indiana Department of Environmental Management (IDEM) have switch their water quality standard for bacterial contamination from fecal coliform to *Escherichia coli*. Of the streams listed in Table 3.19, four exceeded the old IDEM standard of 400 fecal coliform bacteria per 100 mL per water sample for full body contact. Fecal streptococcus counts ranged from less than 1 to 160 cells/100 mL with a mean value of 37 cells/100 mL. The highest fecal streptococcus count was recorded at the outlet of Goose Lake.

Table 3.17

Stream Water Quality During Base Flow Conditions

Lake	Sample Location	pH (S.U.)	Alkalinity (mg/L as $CaCO_3$)	Conductivity (micromhos/cm)	Total Suspended Solids (mg/L)
Goose Lake	Inlet (Northwest)	8.4	114	318	5.5
	Inlet (Southeast)	7.2	174	247	73.0
	Outlet	8.6	108	315	3.4
Loon Lake	Inlet (Winters Ditch)	7.4	188	481	3.1
	Inlet (Old Lake Ditch)	8.1	174	431	12.0
	Inlet (Friskney Ditch)	7.2	110	312	0.2
	Outlet	8.4	152	414	4.5

Table 3.18

Stream Water Quality During Base Flow Conditions

Lake	Sample Location	Nitrate + Nitrate (mg/L)	Ammonia (mg/L)	Total Kjeldahl Nitrogen (mg/L)	Total Phosphorus (mg/L)	Orthophosphate (mg/L)
Goose Lake	Inlet (Northwest)	0.49	<0.1	0.88	0.16	<0.01
	Inlet (Southeast)	0.27	<0.1	0.69	0.52	0.35
	Outlet	0.04	<0.1	0.90	0.04	<0.01
Loon Lake	Inlet (Winters Ditch)	0.39	0.15	1.26	0.23	0.04
	Inlet (Old Lake Ditch)	<0.01	<0.1	1.17	0.17	<0.01
	Inlet (Friskney Ditch)	0.92	<0.1	1.03	0.44	0.20
	Outlet	0.01	<0.1	0.84	0.12	<0.01

Table 3.19 Stream Water Quality During Base Flow Conditions			
Lake	**Sample Location**	**Fecal Coliform (FC) (cells/100 mL)**	**Fecal Streptococcus (FS) (cells/100 mL)**
Goose Lake	Inlet (Northwest)	13,000	20
	Inlet (Southeast)	282,000	20
	Outlet	1,700	160
Loon Lake	Inlet (Winters Ditch)	71,000	40
	Inlet (Old Lake Ditch)	70	10
	Inlet (Friskney Ditch)	60	10
	Outlet	200	<1

Stormflow Conditions

In order to assess the water quality of streams during stormflow conditions, the Loon and Goose Lakes outlets, five lake tributaries, two drainage swales to Loon Lake, and two drainage swales to Goose Lake, were sampled on October 4, 1990. The drainage swales are usually dry under baseflow conditions but contribute flows to the lakes under stormflow conditions. All water samples were analyzed for total phosphorus, orthophosphorus, nitrate plus nitrite, ammonia, total Kjeldahl nitrogen, pH, alkalinity, conductivity, fecal coliform and fecal streptococcus. Streamflow water quality data for October 4, 1990, is presented in Tables 3.20 through 3.22.

On October 3 and October 4, 1991, Fort Wayne, Indiana received 0.94 and 0.33 inches of precipitation (National Weather Service at the Fort Wayne Airport, personal communication). Goose Lake is approximately 25 miles northwest of the Fort Wayne Airport.

In Table 3.20, pH, alkalinity, conductivity and total suspended solid concentrations are shown for eleven streams. For these streams, the pH ranged from 7.0 to 8.0 standard units with mean value of 7.5. For most surface waters, pH values typically fall within a range of 6 to 9 standard units. Alkalinity ranged from 86 to 296 mg/L as calcium carbonate with a mean concentration of 176 mg/L.

Conductivity ranged from 331 to 696 micromhos with a mean value of 487 micromhos. For both surface water and groundwater, conductivity values typically range from 50 to 1500 micromhos. For these streams, total suspended concentrations ranged from 1.0 to 703.1 mg/L with a mean concentrations of 86.2 mg/L. The highest total suspended solids concentration was measured in the southeast inlet to Goose Lake and lowest concentration was recorded at Swale No. 3 for Goose Lake.

In Table 3.21, nitrate plus nitrite, ammonia, total Kjeldahl nitrogen, total phosphorus and orthophosphorus concentrations are shown for the streams in the Loon and Goose Lakes watershed. Nitrate plus nitrate concentrations ranged from less than 0.01 to 5.23 mg/L as nitrogen with a mean concentrations of 1.59 mg/L. Ammonia nitrogen levels ranged from less than 0.10 to 0.27 mg/L as nitrogen with a mean concentration of less than 0.10 mg/L. Of the eleven streams analyzed, seven streams recorded values below the detection limit. Total Kjeldahl nitrogen concentrations ranged from 0.59 to 2.76 mg/L as nitrogen with a mean level of 1.56 mg/L.

For the eleven streams that were sampled, total phosphorus concentrations ranged from 0.06 to 1.71 mg/L as phosphorus with a mean value of 0.46 mg/L as phosphorus. The highest total phosphorus concentrations were recorded in the Southeast inlet to Goose Lake. Orthophosphorus concentrations ranged from less than 0.01 to 0.47 mg/L as phosphorus. The mean orthophosphorus concentration was 0.12 mg/L as phosphorus and the highest orthophosphorus concentration were once again recorded in the Southeast inlet to Goose Lake.

Fecal coliform and fecal streptococcus counts are shown in Table 3.22 for streams within the Loon and Goose Lakes watershed. During transportation, five of the eleven stream samples were damaged, therefore only six samples were analyzed. For these six stream samples, fecal coliform counts were all less than 2 cells/100 mL. Recently, the Indiana Department of Environmental Management (IDEM) have switch their water quality standard for bacterial contamination from fecal coliform to *Escherichia coli*. Of the streams listed in Table 3.22, all the streams recorded cell counts below the old IDEM standard of 400 fecal coliform bacteria per 100 mL per water sample for full body contact. As for fecal streptococcus, counts ranged from 160 to 2,542 cells/100 mL with a mean value of 1,107 cells/100 mL. The highest fecal streptococcus count was recorded in the Friskney Ditch inlet to Loon Lake.

Table 3.20

Stream Water Quality During Stormflow Conditions

Lake	Sample Location	pH (S.U.)	Alkalinity (mg/L as $CaCO_3$)	Conductivity (micromhos/cm)	Total Suspended Solids (mg/L)
Goose Lake	Inlet (Northwest)	7.4	116	336	87.1
	Inlet (Southeast)	7.2	86	331	703.1
	Inlet (Swale No. 3)	7.8	128	335	1.0
	Inlet (Swale No. 2)	7.0	248	650	4.4
	Outlet	7.7	126	362	1.4
Loon Lake	Inlet (Winters Ditch)	7.2	212	275	12.9
	Inlet (Old Lake Ditch)	7.9	196	466	10.3
	Inlet (Friskney Ditch)	7.4	144	505	78.9
	Inlet (Swale No. 1)	7.7	296	658	26.5
	Inlet (Swale No. 2)	7.0	228	696	16.7
	Outlet	8.0	160	448	5.6

Table 3.21

Stream Water Quality During Stormflow Conditions

Lake	Sample Location	Nitrate + Nitrate (mg/L)	Ammonia (mg/L)	Total Kjeldahl Nitrogen (mg/L)	Total Phosphorus (mg/L)	Orthophosphate (mg/L)
Goose Lake	Inlet (Northwest)	1.00	0.10	1.04	0.37	0.09
	Inlet (Southeast)	1.52	<0.10	2.76	1.71	0.47
	Inlet (Swale No. 3)	<0.01	<0.10	1.09	0.08	0.03
	Inlet (Swale No. 2)	2.23	0.27	1.94	0.37	0.22
	Outlet	<0.01	<0.10	0.99	0.04	<0.01
Loon Lake	Inlet (Winters Ditch)	3.19	0.13	2.28	0.35	0.20
	Inlet (Old Lake Ditch)	0.20	<0.10	1.29	0.06	0.03
	Inlet (Friskney Ditch)	3.19	<0.10	1.78	0.49	0.23
	Inlet (Swale No. 1)	0.88	<0.10	0.59	0.15	0.03
	Inlet (Swale No. 2)	5.23	0.13	2.59	0.17	0.05
	Outlet	<0.01	<0.10	0.80	0.06	<0.01

Table 3.22 Stream Water Quality During Stormflow Conditions			
Lake	**Sample Location**	**Fecal Coliform (FC) (cells/100 mL)**	**Fecal Streptococcus (FS) (cells/100 mL)**
Goose Lake	Inlet (Northwest)	<2	2,260
	Inlet (Swale No. 3)	<2	336
	Outlet	<2	160
Loon Lake	Inlet (Winters Ditch)	<2	1,120
	Inlet (Old Lake Ditch)	<2	224
	Inlet (Friskney Ditch)	<2	2,542

Baseflow versus Stormflow Conditions

Based on the data presented in Tables 3.17 through 3.22, the alkalinity, conductivity, total suspended solids, hydrogen ion concentration, and nutrient concentrations are generally higher under stormflow conditions than under baseflow conditions. The hydrogen ion concentration is the inverse antilog of the pH value, therefore as the pH decreases, the hydrogen ion concentration increases.

Under baseflow conditions, fecal coliform bacteria concentrations were greater than fecal streptococcus bacteria concentrations, but when streamflows increase, the situation is reversed. Under stormflow conditions, fecal streptococcus bacteria concentrations were greater than fecal coliform concentrations. In generally, human waste contains higher concentrations of fecal coliform than fecal streptococcus bacteria, while the opposite is true for animal wastes. Based on this statement, one pausible explanation for the observed results is as follows. Under stormflow conditions, more fecal streptococcus bacteria are washed into streams from adjacent agricultural lands (i.e. manure applications on farmland, livestock grazing areas). As for fecal coliform concentrations, the majority of these bacteria are likey delivered to streams via failing septic systems. Therefore, fecal coliform bacteria concentrations are likely reduced through dilution as streamflows increase.

4.0 Pollutant Sources

Pollutants can enter a lake from both point and nonpoint sources. Point sources are defined as all wastewater effluent discharges within a watershed. All point source dischargers of municipal and industrial waste are required to operate under a permit and are assigned a specific discharge number by the National Pollutant Discharge Elimination System (NPDES). The permit requirements determine the amounts of specified pollutants which can be present in the waste effluent for each discharger and also contain monitoring requirements to ensure that discharge limitations are observed. Point sources can include industrial, municipal, and domestic discharges.

All other pollutant sources within a watershed are classified as nonpoint sources. Nonpoint sources can contribute pollutants to a lake through inflow from tributaries, direct runoff, direct precipitation on the lake surface, or through internal loading and groundwater inputs. Both natural events, such as precipitation and runoff, and human activities, including agriculture, silviculture, and construction, can contribute pollutants from nonpoint sources. Nonpoint sources can be difficult to quantify but are important because they often constitute the major source of pollutants to a lake.

Calculations of pollutant loads require information on the water quality of influent streams, knowledge of lake and watershed interactions, and hydrology, and also require data analysis, modeling, and engineering assumptions. Many sources of error can be incorporated into the results because of the number of water quality samples which must be analyzed, the data analysis required, and the number of assumptions which must be made.

Errors resulting from the water quality analyses can be minimized through a good laboratory quality assurance/quality control program, but the other errors involved can only be reduced through the collection of large amounts of chemical and hydrologic data from the entire watershed. This approach would be technically impractical and economically infeasible. As a result, the pollutant loads presented in this report should be considered as best estimates rather than absolute values of the actual pollutant loads.

4.1 Hydrologic Budget

No direct flow measurements were made on any of the lake inlets or at the lake outlet during this study; however, estimates can be made by using data from USGS monitoring stations on similar watersheds nearby. There are two USGS monitoring stations that are close enough to the Loon and Goose watersheds in size and location to be used for these estimates (Glatfelter et al., 1988). Average estimated discharges for the entire Loon

Lake drainage basin and for the Goose Lake drainage basin were calculated by multiplying the average annual discharge per square mile (cfs-m) at the USGS monitoring gages by the area of the drainage basin of interest. Table 4.1 presents the pertinent data from the two USGS stations used to estimate annual discharge of the Loon and Goose Lake watersheds.

Table 4.1
Data from USGS Stations Used to Estimate Discharge at Loon Lake and Goose Lake

Station ID	Station Description	Drainage Area (mi^2)	Average Annual Discharge (cfs)	Period of Record (years)	cfs/mi^2
04100252	Forker Creek Near Burr Oak	19.2	17.8	19	0.927
04100295	Rimmell Branch near Albion	10.7	11.1	8	1.037
Averages		14.95	14.45		0.982

4.1.1 Loon Lake

The Loon Lake watershed includes the Goose Lake watershed and is 9.63 square miles in size. The estimated average annual discharge from the Loon Lake watershed is therefore 9.45 cfs (0.27 m^3/s), using the average cfs/mi^2 calculated in Table 4.1. Based on this estimate, various hydraulic parameters for Loon Lake are presented in Table 4.2.

Table 4.2
Hydraulic Characteristics of Loon Lake

Parameter	Value
Annual Discharge	8,451,648 m^3/yr
Areal Water Load	9.41 m/yr
Flushing Rate	1.2 times per year
Water Renewal Time	0.8 years
Phosphorus Retention Coefficient	56 percent

The annual discharge describes the volume of water that passes through the lake in one years time. The areal water load is equal to the annual discharge divided by the lake's surface area and describes the volume of water per unit of surface area. The flushing rate is the number of times per year the entire lake volume is replaced by inflowing water.

The water renewal time is the inverse of the flushing rate and describes how many years it takes to replace the entire lake volume. The phosphorus retention coefficient describes what percentage of the phosphorus that enters the lake will remain, rather than pass through the outlet. The phosphorus retention coefficient was determined by using the empirical equation developed by Kirchner and Dillon (1975).

4.1.2 Goose Lake

The Goose Lake watershed is 1.44 square miles in size. The estimated average annual discharge from the Goose Lake watershed is therefore 1.41 cfs (0.04 m^3/s), using the average cfs/mi^2 calculated in Table 4.1. Based on this estimate, various hydraulic parameters for Goose Lake are presented in Table 4.3. The parameters are described in the previous section.

Table 4.3
Hydraulic Characteristics of Goose Lake

Parameter	Value
Annual Discharge	1,258,286 m^3/yr
Areal Water Load	3.70 m/yr
Flushing Rate	0.5 times per year
Water Renewal Time	2.0 years
Phosphorus Retention Coefficient	71 percent

4.2 Pollutant Budgets

4.2.1 Loon Lake - Point Source Pollutant Loads

There are no known point source discharges in the Loon Lake watershed.

4.2.2 Loon Lake - Nonpoint Source Pollutant Loads

Watershed Pollutant Loads

Nonpoint source pollutant loadings for lakes can be assessed through an extensive lake and stream monitoring program or through the use of the unit areal loading (UAL) approach (U.S. EPA, 1980). The monitoring approach requires that influent streams be analyzed for flow and pollutant concentrations during both wet and dry weather to determine average pollutant loadings. The unit areal loading approach is based on the premise that different types of land use contribute different quantities of pollutants through runoff.

The unit areal loading (UAL) approach is recommended for the estimation of pollutant inputs from nonpoint sources for watersheds where extensive stream monitoring data is not available (U.S. EPA, 1980). A combination of unit areal loadings for nutrient data and the universal soil loss equation (USLE) for the calculation of total suspended solids loads was used to develop nonpoint source pollutant budgets for Loon Lake.

Average nutrient export coefficients compiled by Reckhow et al. (1980) were used to estimate nonpoint pollutant loading from the various landuses within the watersheds. The coefficients reported by Reckhow et al. (1980) were also chosen for precipitation inputs of phosphorus and nitrogen. All precipitation inputs refer to direct precipitation on the lake surface.

The universal soil loss equation (USLE) was used to calculate sediment loadings to Loon Lake and Goose Lake from agricultural and forested lands. This equation has the form:

$$A = RKLSCP \tag{1}$$

where A = soil loss (tons/acre/yr),
R = Number of erosion index units in a normal year's rain,
K = Soil erodibility factor,
L = Slope length factor,
S = Slope gradient factor,
C = Cropping management factor, and
P = Erosion control practice factor.

Values for each of the terms in the USLE are typically available from the local Soil Conservation Service or from other SCS publications. A weighted average value for RKLSP of 66.49 for agricultural lands, assuming a P factor of 1.0, was obtained from data provided by the Whitley County SCS office for each soil unit. Since 60 percent of the agricultural land is in crop with a P factor of 1.0 (personal communication, Joe Updike, Whitley SCS) and the remaining agricultural land is in pasture/fallow with a P factor of 0.3 (Woodland, 1975), the base RKLSP was multiplied by a P factor of 0.3 to yield a final RKLSP of 19.95 for agricultural land that is in pasture or fallow. The base RKLSP of 66.49 was multiplied by a P factor of 0.1 (Woodland, 1975) to yield an RKLSP for forested land of 6.65. The average typical C factor for agricultural land in the watershed is 0.125 (personal communication, Joe Updike, Whitley SCS). A C factor for forested land of 0.003 was selected from Wischmeir and Smith (1978).

Calculated soil losses are presented in Table 4.4. A sediment delivery rate to Loon Lake of 5 percent of the calculated soil loss was assumed based on past studies and personal communication with Whitley County SCS and the resulting total suspended solids loadings to Loon Lake are included in Table 4.5.

Total suspended solids loadings from precipitation were estimated from the average total suspended solids concentration in rainfall of 3 mg/L reported for a study in Virginia (F. X. Browne Associates, 1982) and the average annual rainfall in the study area of 36.25 inches (Glatfelter et al., 1988). The total suspended solids loading to Loon Lake from precipitation calculated from these values was 27.62 kg/ha/yr (60.89 lbs/acre/year).

Table 4.4
Calculated Soil Loss in the Loon Lake Watershed

Land Use	USLE Parameter	Soil Loss	Delivery Ratio	Soil Delivery
Agriculture Row Crop	RKLSP = 66.49 C = 0.125	8.31 tons/ac/yr 20,864 kg/ha/yr	0.05	0.42 tons/ac/yr 1,043 kg/ha/yr
Agriculture Feedlots	RKLSP = 66.49 C = 1.0	66.49 tons/ac/yr 166,937 kg/ha/yr	0.05	3.32 tons/ac/yr 8,347 kg/ha/yr
Agriculture Pasture	RKLSP = 19.95 C = 0.125	2.49 tons/ac/yr 6,252 kg/ha/yr	0.05	0.12 tons/ac/yr 313 kg/ha/yr
Forest	RKLSP = 6.65 C = 0.003	0.02 tons/ac/yr 50 kg/ha/yr	0.05	0.001 tons/ac/yr 2.5 kg/ha/yr

Table 4.5 presents the Unit Area Loading calculations for the Loon Lake direct watershed, not including the land that drains through Goose Lake. There were seven feedlots identified by field reconnaissance and the SCS within the watershed. Assuming one half acre per site and phosphorus and nitrogen loading rates from Reckhow et al. (1980), these sites contribute an estimated 346.5 kg of phosphorus (764 pounds) and 4,140.9 kg of nitrogen (9,129 pounds) and 1,481.1 kg of to the annual nutrient budget.

Pollutant Loadings from Septic Leachate

Loon Lake has a total of 259 homes within 1,000 feet of the lake. Since the soils within the watershed are generally poorly suited for subsurface wastewater disposal, homes within this area can be considered to have a potential for impacting water quality due to septic leachate.

In order to estimate the phosphorus and nitrogen inputs to the lake from septic systems, the following equations were used:

Phosphorus Load From Septic Systems = (#homes) X (Avg People/Home) X (0.005 lb phosphorus/person*) X (days occupied/year).

Nitrogen Load From Septic Systems = (#homes) X (Avg People/Home) X (0.028 lb nitrogen/person**) X (days occupied/year)

* Phosphorus loading coefficient based on Indiana field data

** Nitrogen loading coefficients is the median values reported by Reckhow (1980) for household wastewater.

Table 4.5
Unit Area Loadings for the Loon Lake Direct Watershed

Land Use	*Area*	*Parameter*	*Loading Coefficient*	*Annual Load*
Wetlands/upstream waterbodies	125.6 hectares 310.3 acres	Total P Total N TSS		
Residential	47.2 hectares 116.7 acres	Total P Total N TSS	1.100 kg/ha/yr 5.500 kg/ha/yr 313 kg/ha/yr	51.9 kg/yr (114.4 lbs/yr) 259.6 kg/yr (572.3 lbs/yr) 14,773.6 kg/yr (32,569.9 lbs/yr)
Forest	288.6 hectares 713.1 acres	Total P Total N TSS	0.206 kg/ha/yr 2.460 kg/ha/yr 2.5 kg/ha/yr	59.4 kg/yr (131.0 lbs/yr) 710.0 kg/yr (1,565.3 lbs/yr) 721.5 kg/yr (1,590.6 lbs/yr)
Agriculture Feedlots	1.4 hectares 3.5 acres	Total P Total N TSS	244.0 kg/ha/yr 2,923.2 kg/ha/yr 8,347 kg/ha/yr	341.6 kg/yr (753.1 lbs/yr) 4,092.5 kg/yr (9,022.3 lbs/yr) 11,685.8 kg/yr (25,762.5 lbs/yr)
Agriculture Row crops	995.7 hectares 2,460.4 acres	Total P Total N TSS	2.240 kg/ha/yr 9.000 kg/ha/yr 1,043 kg/ha/yr	2,230.4 kg/yr (4,917.1 lbs/yr) 8,961.3 kg/yr (19,756.1 lbs/yr) 1,038,515 kg/yr (2,289,510 lbs/yr)
Agriculture Pasture	663.8 hectares 1,640.3 acres	Total P Total N TSS	0.760 kg/ha/yr 6.080 kg/ha/yr 313 kg/ha/yr	504.5 kg/yr (1,112.2 lbs/yr) 4,035.9 kg/yr (8,897.5 lbs/yr) 207,769 kg/yr (458,048 lbs/yr)
Direct Precipitation on Lake Surface	90.0 hectares 222.0 acres	Total P Total N TSS	0.45 kg/ha/yr 20.98 kg/ha/yr 27.62 kg/ha/yr	40.5 kg/yr (89.3 lbs/yr) 1,888.2 kg/yr (4,162.7 lbs/yr) 2,485.8 kg/yr (5,480.2 lbs/yr)
Total Drainage Area	2,120.9 hectares 5,240.8 acres	Total P Total N TSS		3,228 kg/yr (7,117 lbs/yr) 19,948 kg/yr (43,976 lbs/yr) 1,275,951 kg/yr (2,812,961 lbs/yr)

Several assumptions were made to estimate a phosphorus and nitrogen loading to the lake. High risk homes were considered to be lakefront homes. The average number of occupants in year-round homes was considered to be 2.5, while the average number increases to 3.5 for seasonally used dwellings. Seasonal use was considered to be 98 days. Since soil has a certain capacity to treat wastewater, a soil retention factor was applied to the septic system loads (Canter and Knox, 1986). In selecting soil retention factors, local soil conditions near the lakes were considered. Soil retention of nutrients was considered to be higher for low risk homes. The factors used in the loading calculations and the results are presented in Table 4.6.

Table 4.6
Estimated Loading to Loon Lake by Septic Systems

Dwelling Class		*Number of Units*	*Parameter*	*Septic Load*	*Soil Retention Coefficient*	*Nutrient Load to Lake*
Low Risk	Year-round	47	Total Phosphorus Total Nitrogen	214 lbs/yr 1,201 lbs/yr	0.50 0.10	107 lbs/yr 1,081 lbs/yr
	Seasonal	16	Total Phosphorus Total Nitrogen	27 lbs/yr 154 lbs/yr	0.50 0.10	14 lbs/yr 139 lbs/yr
High Risk	Year-round	92	Total Phosphorus Total Nitrogen	433 lbs/yr 2,351 lbs/yr	0.25 0.05	325 lbs/yr 2,233 lbs/yr
	Seasonal	104	Total Phosphorus Total Nitrogen	178 lbs/yr 999 lbs/yr	0.25 0.05	134 lbs/yr 949 lbs/yr
TOTALS		259	Total Phosphorus Total Nitrogen			580 lbs/yr 4,402 lbs/yr

Pollutant Loadings from Upstream Lakes

A phosphorus retention coefficient of 0.71 has been calculated for Goose Lake, which is directly upstream of Loon Lake. This means that 71 percent of the phosphorus load to Goose Lake is retained by this system, while the remainder passes into Loon Lake. The above retention coefficient has been applied to loading values form Goose Lake and the results are presented in the pollutant budget for Loon Lake.

4.2.3 Loon Lake - Pollutant Budget Summary

Non-point sources other than septic systems, precipitation falling on the lake surface, and upstream loadings from the Goose Lake subwatershed, contribute on an annual basis 3,188 kilograms of phosphorus (7,028 lbs), 18,060 kilograms of nitrogen (39,813 lbs) and 1,273,465 kilograms of suspended solids (2,807,481 lbs). Septic systems contribute an additional 263 kilograms of phosphorus (580 lbs) and 1,997 kilograms of nitrogen (4,402 lbs). As can be seen in Table 4.7 and Figure 4.1, septic systems accounts for 7.2 percent of the annual phosphorus load and 8.7 percent of the annual nitrogen load to

Loon Lake. While septic systems may only contribute twelve percent of the annual nutrient load to Loon Lake, it is important to realize that this load is primarily being released directly to the shallow waters of the lake, where excessive weed growth is a problem.

Table 4.7
Pollutant Budget Summary for Loon Lake Watershed

Category	Parameter	Loading kg/year	Loading lbs/year	Loading Percent
Nonpoint Sources	Phosphorus	3,188	7,028	87.0
	Nitrogen	18,060	39,813	78.4
	Suspended Solids	1,273,465	2,807,481	94.9
Septic Systems	Phosphorus	263	580	7.2
	Nitrogen	1,997	4,402	8.7
	Suspended Solids	0	0	0.0
Precipitation	Phosphorus	40	89	1.1
	Nitrogen	1,888	4,163	8.2
	Suspended Solids	2,486	5,480	0.2
Upstream Load	Phosphorus	171	377	4.7
	Nitrogen	1,095	2,415	4.7
	Suspended Solids	65,422	144,229	4.9
TOTALS	Phosphorus	3,662	8,074	100.0
	Nitrogen	23,040	50,793	100.0
	Suspended Solids	1,341,373	2,957,190	100.0

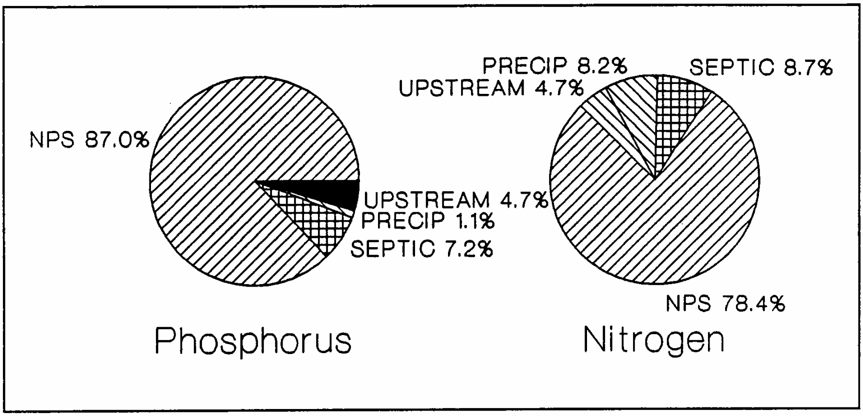

Figure 4.1 Percent contribution to the Loon Lake watershed nutrient budgets

4.2.4 Goose Lake - Point Source Pollutant Loads

There are no known point source discharges in the Loon Lake watershed.

4.2.5 Goose Lake - Nonpoint Source Pollutant Loads

<u>**Watershed Pollutant Loadings**</u>

Unit Area Loading calculations were used to calculate nonpoint source loading to Goose Lake in the same manner as described above for Loon Lake. The Universal Soil Loss Equation was used to estimate suspended solids loads, also in the same manner as described above. Total suspended solids loadings from precipitation were estimated from the average total suspended solids concentration in rainfall of 3 mg/L reported for a study in Virginia (F. X. Browne Associates, 1982) and the average annual rainfall in the study area of 36.25 inches (Glatfelter, et al., 1988). The total suspended solids loading to Loon Lake from precipitation calculated from these values was 27.62 kg/ha/yr (60.89 lbs/acre/year).

Table 4.8 presents the Unit Area Loading calculations for the Goose Lake watershed.

Pollutant Loadings from Septic Leachate

Goose Lake has a total of 78 homes within 1,000 feet of the lake. Since the soils within the watershed are generally poorly suited for subsurface wastewater disposal, homes within this area can be considered to have a potential for impacting water quality due to septic leachate. Phosphorus and nitrogen inputs to the lake from septic systems were estimated in the manner described above.

Table 4.8
Unit Area Loadings for the Goose Lake Watershed

Land Use	*Area*	*Parameter*	*Loading Coefficient*	*Annual Load*
Wetlands/upstream waterbodies	58.2 hectares 143.8 acres	Total P Total N TSS		
Residential	5.8 hectares 14.3 acres	Total P Total N TSS	1.100 kg/ha/yr 5.500 kg/ha/yr 313 kg/ha/yr	6.4 kg/yr (14.1 lbs/yr) 31.9 kg/yr (70.3 lbs/yr) 1,815.4 kg/yr (4,002.2 lbs/yr)
Forest	12.7 hectares 31.4 acres	Total P Total N TSS	0.206 kg/ha/yr 2.460 kg/ha/yr 2.5 kg/ha/yr	2.6 kg/yr (5.7 lbs/yr) 31.2 kg/yr (68.8 lbs/yr) 31.8 kg/yr (70.1 lbs/yr)
Agriculture Feedlots	0.0 hectares 0.0 acres	Total P Total N TSS	244.0 kg/ha/yr 2,923.2 kg/ha/yr 8,347 kg/ha/yr	0.0 kg/yr (0.0 lbs/yr) 0.0 kg/yr (0.0 lbs/yr) 0.0 kg/yr (0.0 lbs/yr)
Agriculture Row crops	178.0 hectares 439.8 acres	Total P Total N TSS	2.240 kg/ha/yr 9.000 kg/ha/yr 1,043 kg/ha/yr	398.7 kg/yr (879.0 lbs/yr) 1,602.0 kg/yr (3,531.8 lbs/yr) 185,654.0 kg/yr (409,292.8 lbs/yr)
Agriculture Pasture	118.7 hectares 293.3 acres	Total P Total N TSS	0.760 kg/ha/yr 6.080 kg/ha/yr 313 kg/ha/yr	90.2 kg/yr (198.8 lbs/yr) 721.7 kg/yr (1,591.1 lbs/yr) 37,153.0 kg/yr (81,907.5 lbs/yr)
Direct Precipitation on Lake Surface	34.0 hectares 84.0 acres	Total P Total N TSS	0.45 kg/ha/yr 20.98 kg/ha/yr 27.62 kg/ha/yr	15.3 kg/yr (33.7 lbs/yr) 713.3 kg/yr (1,572.6 lbs/yr) 939.1 kg/yr (2,070.3 lbs/yr)
Total Drainage Area	2,120.9 hectares 5,240.8 acres	Total P Total N TSS		513 kg/yr (1,131 lbs/yr) 3,100 kg/yr (6,835 lbs/yr) 225,593 kg/yr (497,343 lbs/yr)

Several assumptions were made to estimate a phosphorus and nitrogen loading to the lake. High risk homes were considered to be lakefront homes. The average number of occupants in year-round homes was considered to be 2.5, while the average number increases to 3.5 for seasonally used dwellings. Seasonal use was considered to be 98 days. Since soil has a certain capacity to treat wastewater, a soil retention factor was applied to the septic system loads (Canter and Knox, 1986). Soil retention of nutrients was considered to be higher for low risk homes. The factors used in the loading calculations and the results are presented in Table 4.9. These numbers should be considered low estimates since there was no good way to factor in the restaurant or trailer park usage.

Table 4.9
Estimated Loading to Goose Lake by Septic Systems

Dwelling Class		*Number of Units*	*Parameter*	*Septic Load*	*Soil Retention Coefficient*	*Nutrient Load to Lake*
Low Risk	Year-round	35	Total Phosphorus Total Nitrogen	160 lbs/yr 894 lbs/yr	0.50 0.10	80 lbs/yr 805 lbs/yr
	Seasonal	15	Total Phosphorus Total Nitrogen	26 lbs/yr 144 lbs/yr	0.50 0.10	13 lbs/yr 130 lbs/yr
High Risk	Year-round	20	Total Phosphorus Total Nitrogen	91 lbs/yr 511 lbs/yr	0.25 0.05	68 lbs/yr 485 lbs/yr
	Seasonal	8	Total Phosphorus Total Nitrogen	14 lbs/yr 77 lbs/yr	0.25 0.05	10 lbs/yr 73 lbs/yr
TOTALS		78	Total Phosphorus Total Nitrogen			171 lbs/yr 1,493 lbs/yr

4.2.6 Goose Lake - Pollutant Budget Summary

Non-point sources other than septic systems and precipitation falling directly on the lake surface, contribute on an annual basis 498 kilograms of phosphorus (1,098 lbs), 2,387 kilograms of nitrogen (5,262 lbs) and 224,654 kilograms of suspended solids (495,273 lbs). Septic systems contribute an additional 78 kilograms of phosphorus (171 lbs) and 677 kilograms of nitrogen (1,493 lbs). As can be seen in Table 4.10 and Figure 4.2, septic systems accounts for 13.2 percent of the annual phosphorus load and 17.9 percent of the annual nitrogen load to Goose Lake. This large percent contribution of septic systems to the annual nutrient budget of Goose Lake is due to the relatively small watershed area of the lake. It is important to realize that this load is primarily being released directly to the shallow waters of the lake, where excessive weed growth is a problem.

Table 4.10 Pollutant Budget Summary for Goose Lake Watershed				
Category	Parameter	Loading kg/year	Loading lbs/year	Loading Percent
Nonpoint Sources	Phosphorus Nitrogen Suspended Solids	498 2,387 224,654	1,098 5,262 495,273	84.3 63.2 99.6
Septic Systems	Phosphorus Nitrogen Suspended Solids	78 677 0	171 1,493 0	13.2 17.9 0.0
Precipitation	Phosphorus Nitrogen Suspended Solids	15 713 939	33 1,572 2,070	2.5 18.9 0.4
TOTALS	Phosphorus Nitrogen Suspended Solids	591 3,777 225,593	1,302 8,327 497,343	100.0 100.0 100.0

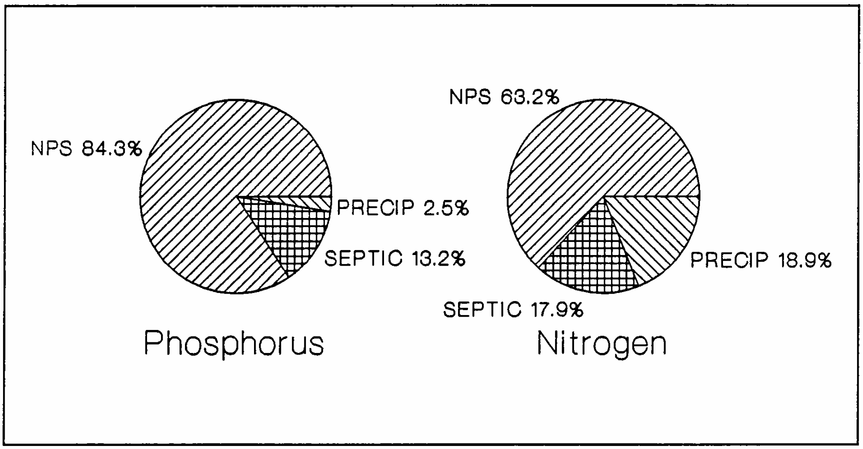

Figure 4.2 Percent contribution to the Goose Lake watershed nutrient budgets

4.3 Phosphorus Modeling

Estimates of the maximum permissible pollutant loading to a lake can be calculated using the widely used Dillon and Rigler (1975) and Vollenweider (1977) models. The Dillon and Rigler model predicts annual mean total phosphorus concentrations using the formula:

$$TP = L(1-R)/pz$$

where TP = annual mean phosphorus concentration (g/m3)
L = areal phosphorus loading (g/m2/yr)
R = phosphorus retention coefficient
p = flushing rate (times/yr)
z = mean depth (m)

Using previously calculated values, we can predict the annual mean phosphorus concentration in Loon and Goose Lakes. The phosphorus loading can then be varied until we reach an acceptable total phosphorus level, which is described by Vollenweider (1977) as 0.02 g/m3. Comparing this to the estimated current phosphorus load, we can come up with the percent reduction needed to improve the lake's water quality.

4.3.1 Loon Lake

Substituting values from Section 4.1.1 and the nutrient loading sections into the Dillon and Rigler equation, we get a predicted mean total phosphorus concentration for Loon Lake of 0.19 mg/L, which compares favorably with the one day measured average of 0.15 mg/L. Rearranging the Dillon and Rigler formula and using the predicted mean total phosphorus concentration, phosphorus loading must be reduced by 90 percent to improve water quality to a mesotrophic condition.

4.3.2 Goose Lake

Substituting values from Section 4.1.2 and the nutrient loading sections into the Dillon and Rigler equation, we get a predicted mean total phosphorus concentration for Goose Lake of 0.14 mg/L, which compares favorably with the one day measured average of 0.17 mg/L. Rearranging the Dillon and Rigler formula and using the predicted mean total phosphorus concentration, phosphorus loading must be reduced by 85 percent to improve water quality to a mesotrophic condition.

5.0 Evaluation of Lake Restoration Alternatives

Management alternatives for Loon and Goose Lakes were divided into two categories: watershed management alternatives and in-lake management alternatives. The first priority in all management programs is to determine whether watershed management practices can be implemented to reduce the pollutants entering the lake. Because nonpoint source pollutants account for a high percentage of the nutrient and sediment loading to Loon and Goose Lakes, it is critical that lake restoration focuses on watershed controls. If watershed controls are not implemented, then the recommended in-lake restoration will have little effect towards improving water quality.
The following sections discuss the in-lake and watershed restoration methods that are applicable to Loon Lake and Goose Lake. A list of potential watershed and in-lake management alternatives are listed below:

A. Watershed Management Alternatives
   1. Wastewater Treatment
   2. Diversion of Wastewater
   3. Watershed Management Practices
   4. Homeowner Management Practices
   5. Septic System Management Practices
   6. Development of Model Ordinances

B. In-lake Management Alternatives
   1. Lake Aeration
      a. Aeration
      b. Mechanical Circulation

   2. Lake Deepening
      a. Dredging
      b. Drawdown and Sediment Consolidation
      c. Raise Lake Surface Elevation

   3. Other Physical Controls
      a. Harvesting of Nuisance Biomass
      b. Water Level Fluctuation
      c. Habitat Manipulation
      d. Covering Bottom Sediments to Control Macrophytes

   4. Chemical Controls
      a. Algicides
      b. Herbicides
      c. Pesticides

5. Biological Controls
   a. Predator-prey relationships
   b. Intra- and inter-specific manipulation
   c. Pathologic reactions

6. In-lake Schemes to Accelerate Nutrient Outflow or Prevent Recycling
   a. Dredging for nutrient control
   b. Nutrient Inactivation/Precipitation
   c. Dilution/flushing
   d. Biotic harvesting for nutrient removal
   e. Selective discharge from impoundments
   f. Sediment exposure and desiccation
   g. Lake bottom sealing

The following criteria were used in the evaluation of potential management alternatives:

Effectiveness	-	how well a specific management practice meets its goal
Longevity	-	reflects the duration of treatment effectiveness
Confidence	-	refers to the number and quality of reports and studies supporting the effectiveness rating given to a specific treatment
Applicability	-	refers to whether or not the treatment directly affects the cause of the problem and whether it is suitable for the region in which it is considered for application
Potential for Negative Impacts	-	an evaluation should be made to insure that a proposed management practice does not cause a negative impact on the lake ecosystem
Capital Costs	-	standard approaches should be used to evaluate the cost- effectiveness of various alternatives
Operation and Maintenance Costs	-	these costs should be evaluated to help determine the cost-effectiveness of each management alternative

5.1 In-Lake Restoration Methods

This section discusses some of the more widely accepted in-lake restoration methods for improving water quality. These techniques are aimed at controlling aquatic vegetation and algae, improving dissolved oxygen levels, and/or minimizing the internal phosphorus loading from sediments. Each technique is discussed in terms of the basic principles and its appropriateness for use in Loon Lake and Goose Lake. It must be kept in mind that in-lake restoration alone will not result in a noticeable improvement in water quality due to the high watershed pollutant loads. Recreational benefits may result, however, by managing macrophyte densities.

5.1.1 Lake Aeration

Aeration has been widely-used as a restoration measure for lakes where summer hypolimnetic oxygen depletion and/or winter-kill are of major concern. Aeration can be divided into two categories: those methods which destratify the lake water column and circulate the entire lake and those methods which aerate the hypolimnion (deep water layer) without destratifying the lake. Both methods are based on the principle that if you increase the dissolved oxygen concentration in a lake, you will provide additional habitat for fish while decreasing the release of phosphorus from the sediments that occurs under anoxic (low dissolved oxygen) conditions.

Some studies have shown that algae levels may be controlled by destratifying a lake, though most recent works on larger lakes indicate that this effect is only temporary. After a few seasons, algae concentrations may actually increase and bluegreen algae can continue to dominate. Aeration by destratification works by bubbling air from the lake bottom, causing the water column to circulate. This technique requires long-term maintenance and operational costs and is not considered feasible for Loon Lake, which is relatively large and deep.

Hypolimnetic aerators, which do not destratify a lake, work by lifting aerating hypolimnetic water in a closed chamber and circulating the aerated water back into the hypolimnion. The major concerns are the ongoing operational costs of the system.

Based on the morphology and the water quality characteristics of Loon and Goose Lakes, hypolimnetic aeration was selected over destratifying systems because as stated above, these systems would provide a coldwater habitat for coldwater fish species, reduce internal phosphorus loadings from lake sediments, and greatly reduce the risk of nutrient recirculation. For each of the Indiana lakes, the anoxic volume of water was calculated from existing bathymetric maps and dissolved oxygen profiles obtained in the field.

In sizing hypolimnetic aeration systems, an oxygen depletion rate is usually determined from multiple dissolved oxygen profiles recorded throughout the spring and summer months. Since only one dissolved oxygen profile was monitored for each of the lakes, the dissolved oxygen depletion rate was assumed to be 0.3 mg/L per day. The oxygen demand for each lake was determined by multiplying the hypolimnetic volume by the oxygen depletion rate. The actual aerator design was based on lake size and lake shape, and the required oxygen supply rate. The oxygen supply rate is twice the oxygen demand to insure an adequate supply of oxygen.

For both Loon and Goose Lakes, the hypolimnetic aeration sizing requirements plus associated equipment and annual operational costs are described below.

Loon Lake

The anoxic volume of water for Loon Lake was estimated at 3.67 million cubic meters and would require approximately 2,200 kilograms of oxygen per day (oxygen supply rate). Based on the lake morphology and the required oxygen supply rate, five aerators and two (80) horse powered air compressors would be needed. The estimated project cost is $348,000, which includes all major hardware, installation, start-up costs, labor, freight, diving and special equipment expenses. The above project cost does not include housing structures for the compressors, bringing electric power to the site, or the trenching of air lines. Assuming 150 days of operation at $0.08 per kilowatt-hour, the annual operational cost is estimated at $15,200.

Based on the high estimated project and annual operating costs, hypolimnetic aeration does not appear to be a cost-effective management alternative for Loon Lake.

Goose Lake

The anoxic volume of water for Goose Lake was estimated at 1.40 million cubic meters and would require approximately 840 kilograms of oxygen per day (oxygen supply rate). Based on the lake morphology and the required oxygen supply rate, two aerators and one (30) horse powered air compressor would be needed. The estimated project cost is $174,000, which includes all major hardware, installation, start-up costs, labor, freight, diving and special equipment expenses. The above project cost does not include housing structures for the compressors, bringing electric power to the site, or the trenching of air lines. Assuming 150 days of operation at $0.08 per kilowatt-hour, the annual operational cost is estimated at $3,000.

Based on the high estimated project and annual operating costs, hypolimnetic aeration does not appear to be a cost-effective management alternative for Goose Lake.

5.1.2 Dredging

The physical removal of lake sediments can be used to achieve one or more objectives, including macrophyte removal, lake deepening, and nutrient removal. The most obvious advantage of dredging is the immediate removal of virtually all plants from the lake bottom. Therefore, all of the nutrient compounds and organic matter which comprise the existing vegetative biomass are permanently removed from the lake system. The entire macrophyte mass would be eliminated, including the seeds and roots, thereby preventing a quick recurrence of nuisance growths. The drawback to dredging is that natural wetland areas, which are prime fish and wildlife habitat, may be destroyed in the process. The cost of dredging is high and most dredging is limited to depths up to 25 feet.

Problems associated with in-lake dredging are the resuspension of sediments and nutrients, the disturbance of the benthic community, and the disturbance of both fishery nesting and refuge areas. During the dredging operation, sediments and nutrients are often resuspended, which may result in algal blooms, increased turbidity, and decreased dissolved oxygen concentrations. By removing in-lake sediments, many of the residing aquatic organisms will be physically removed or smothered by the settling sediments in areas adjacent to the actual operation. In addition to the benthic community, both fish nesting (breeding) areas and refuge areas for juvenile fishes may also be removed or silted in by sediment. However, the continued improvement of hydraulic dredging equipment and dredging methods have helped to minimize these adverse impacts.

Loon Lake

Plant distribution in Loon Lake is limited by water depth, with macrophytes occurring up to a depth of about five feet. While it would not be feasible to dredge all shallow areas, spot dredging could be undertaken where high siltation rates have created large expanses of macrophyte habitat, such as at the main inlet area near the public access site. However, since a boating channel does exist, and Loon Lake's size and depth provide a wide range of lake uses, dredging is not recommended at this time.

Goose Lake

Plant distribution in Goose Lake is limited by water depth, with macrophytes occurring up to a depth of about five feet. While it would not be feasible to dredge all shallow areas, spot dredging could be undertaken where high siltation rates have created large expanses of macrophyte habitat, such as along the southern and eastern shores. However, since these areas are not in front of residential properties and may actual help to treat runoff from adjacent agricultural activities, dredging is not recommended at this time.

5.1.3 Macrophyte Harvesting

Aquatic weed harvesting is used for two lake restoration purposes: (1) to physically remove nuisance vegetation, and (2) to remove nutrients and organic matter from the lake ecosystem. Harvesting is a direct way to accomplish the first goal with minimal negative impacts. The actual harvesting does not interfere with the use of a lake, improves recreational usage and does not introduce foreign substances (algicides or herbicides) to the ecosystem. Weed harvesting is used primarily to restore the recreational uses of a lake. However, the technique presents a maintenance problem since the equipment seldom removes the entire plant. Most lakes usually require two to three cuttings per year in order to maintain the weeds at a non-nuisance level. The frequency of cutting, however, may be reduced after several years of harvesting.

The advantages of weed harvesting versus chemical application were evaluated for a small lake in Ohio (Conyes and Cooke, 1982). It was concluded that harvesting is much more effective than the recommended doses of Cutrine-Plus and Diquat in controlling the biomass, and harvesting would be less costly over a two-year period than chemical treatment for the same period.

In addition to removing nuisance plant growth, harvesting can result in water quality improvements. Removing intact plants reduces the oxygen demand associated with decaying plants and improves fish habitat. Since up to 50 percent of dead plant tissue deposited on a lake bottom does not decompose, sediment and detrital accumulation rates would decrease with harvesting. The benefit in harvesting macrophytes to remove nutrients is less certain. When possible, plants absorb nutrients in excess of their needs. As much as 0.05 to 0.4 $g/m^2/yr$ of phosphorus can be removed from a lake by mechanical harvesting (Burton, et al., 1979). In order to have a net effect, removal of phosphorus by harvesting would have to exceed the annual phosphorus accumulation rate. Phosphorus removal is affected by the type of harvesting operation, the amount of phosphorus stored in the sediments and taken up by vegetation, and whether nutrient inputs are controlled. Net nutrient removal is likely only in limited instances where nutrient inputs are reduced to low levels. It would most likely take years to deplete the supply of phosphorus stored in the upper layers of the sediment.

Compared to other restoration techniques, the cost of aquatic weed harvesting is moderate. The size and type of harvesting operation determines the type of machinery that should be used and the cost-effectiveness of purchasing equipment versus contracting a harvester. In general, those harvesters that cut the macrophytes and immediately remove them by means of a conveyor are most effective.

The potential negative environmental impacts of harvesting include:

1. A change in the dominant plant species,
2. A change in the composition of benthic and aquatic organisms,
3. Short-term suspension of sediments and detritus,
4. Dissolved oxygen depletion due to plant decomposition,
5. Nutrient release to the water column from decaying plants and ruptured stems, and
6. An increase in algae populations.

The extent and likelihood of these effects depend in part on the completeness of macrophyte removal and on the magnitude of sediment release of nutrients and nonpoint sources of nutrients.

There are several ways to establish a weed harvesting program. They are 1) purchase and run your own harvester, 2) share a harvester with other lakes or establish a county-wide harvesting program, or 3) contract the harvesting to an outside service. Purchasing and running your own harvester is initially the most expensive way to establish a harvesting program. Over the long-term, the initial expense will be offset by the cost of contracting out, but annual operational and maintenance costs will continue. The cost to an individual lake association can be reduced by sharing ownership among several lakes or by establishing a county-wide macrophyte harvesting program.

The cost for equipment depends on the size of the harvester and ranges between \$50,000 and \$120,000 for the mechanical weed harvester, shore conveyor and trailer. Weed harvesters can cut approximately one acre of weeds in 4 to 8 hours and typically cost about \$200 per acre to operate not including the disposal of cut vegetation (New York Department of Environmental Conservation, 1990). The actual time and operational cost will be highly dependent on the harvester unit selected and the density of the macrophytes. The harvester should be able to cut a swath ranging from six to ten feet in width and to a depth of six to eight feet. The use of mechanical harvesters is generally limited to lake depths greater than 2.0 feet and beyond docks due to poor maneuverability. It should be noted the above cost does not include weed disposal.

Instead of a lake association or a county purchasing its own weed harvesting equipment, a lake association may choose to contract out its weed harvesting duties. Typically, contractor rates for weed harvesting are quite variable and greatly depend on the geographic location of the lake and local market prices. Based on conversations with local subcontractors in the region of Loon and Goose Lakes, weed harvesting fees are typically \$75 per hour, therefore weed harvesting in open waters and channels will cost approximately \$225 to \$375 per acre, respectively. The above costs do not include hauling fees to the weed disposal site.

After harvesting, the weeds are usually unloaded from the harvester to trucks via shore conveyor units. Prior to the commencement of any weed harvesting activities, several weed disposal sites should be identified. Aquatic weeds compost well, thereby producing a good mulching material. In many instances, the agricultural community will generally accept harvested weeds. In any of the above approaches to weed harvesting, it is important to find a close disposal site, thereby reducing hauling costs for weed disposal.

Macrophyte harvesting is most applicable and cost-effective in lakes with shallow average depths. Harvesting by machine is generally limited to areas over 2½ feet deep and beyond docks due to poor maneuverability of the machines. This means that those areas where weed removal is most needed would have to be treated by chemical, hand-pulling or by installing barriers.

Loon Lake

Lake-wide weed harvesting is not recommended for Loon Lake. The practice would not be effective in removing a noticeable amount of nutrients from the lake system, given the amount of loading from the watershed. In addition, a certain amount of macrophytes is beneficial to the lake ecosystem. However, harvesting should be considered as an alternative to chemical control that is currently being used in front of individual lakefront properties.

An integrated macrophyte management plan should be established which minimizes the use of chemicals and employs the use of mechanical harvesting, hand-pulling and bottom barriers.

Goose Lake

Lake-wide weed harvesting is not recommended for Goose Lake. The practice would not be effective in removing a noticeable amount of nutrients from the lake system, given the amount of loading from the watershed. In addition, a certain amount of macrophytes is beneficial to the lake ecosystem. However, harvesting should be considered as an alternative to chemical control that is currently being used in front of individual lakefront properties.

An integrated macrophyte management plan should be established which minimizes the use of chemicals and employs the use of mechanical harvesting, hand-pulling and bottom barriers.

5.1.4 Water Level Controls

The intent of water level control is to manipulate the aquatic habitat and create conditions unfavorable to aquatic plant growth. One approach is to raise the water surface elevation. A higher water level deepens a lake, increases the lake volume, and allows less light to reach the bottom of the lake where plants grow. This approach, however, does not address the causes of excessive plant growth--sediment accumulations and high nutrient concentrations. In addition, this method has limited practical applications. Raising the water surface elevation in Loon Lake would require modifications to the dam and spillway structures. Shoreline and habitat at the lakes' edges would be destroyed, and flooding of open space and private property would result.

Water level drawdown is a second approach and has been used for at least the short-term control (one to two years) of susceptible nuisance macrophyte species. The object of water level drawdown is to retard aquatic macrophyte growth by destroying seeds and vegetative reproductive structures through drying or freezing conditions, or by altering their substrate through sediment dewatering. Water level drawdown may also compact the exposed sediments to a certain degree, thereby reducing the need for dredging.

Loon Lake

Drawdown can be implemented at a relatively low cost providing a lake has an outlet structure which can allow a water lowering of at least five feet. Loon Lake does not have such an outlet structure. The outlet channel would have to be deepened and a control structure installed in order to implement this method of lake management. Therefore, water level controls are not considered a viable option for lake management at Loon Lake.

Goose Lake

Goose Lake does not have an outlet structure that allows easy regulation of water depth. The outlet channel would have to be deepened and a control structure installed in order to implement this method of lake management. Therefore, water level controls are not considered a viable option for lake management at Goose Lake.

5.1.5 Chemical Controls

Chemical treatment has been used extensively in lakes to control the growth of aquatic vegetation. Excessive macrophyte and algae growth, can generally be controlled with herbicides and algicides if the proper chemical or combinations of chemicals are selected and properly applied. Over a short period of time chemicals are effective in killing vegetation and restoring the recreational use of a lake, thus their widespread use. Over a long period of time, however, they are unsuccessful. They treat only the symptoms of eutrophication, not the causes.

Excessive growth of aquatic plants and algae could also be reduced through control of nutrients. The best method is to limit the nutrients entering the lake by controlling them at their source with watershed management practices such as land use controls, septic system maintenance, and erosion control. In-lake nutrient controls such as chemical nutrient inactivation can also be effective.

Algicides

Copper sulfate and copper compounds are the most commonly used general algicide. The solubility of copper sulfate and subsequently its effectiveness is influenced by pH, alkalinity, and temperature. Copper sulfate is most effective in soft, mildly acidic waters. If added in excessive amounts, copper sulfate can be toxic to fish and other aquatic life. It can also accumulate in the lake sediments. One of the problems with the use of copper sulfate is its specificity for only certain algae. It is successful in causing a change in the dominant species of algae in a body of water. There are times when the algae replacing the original problem species cause problems of their own, and these latter algae are not controlled by usual treatments of copper sulfate.

Copper sulfate costs ranged $5 to $25 per acre-foot in 1990 (NY DEC, 1990). This cost range does not include applicator's fees. Assuming a 5 percent inflation rate, the cost for copper sulfate is estimated at $5.50 to $27.60 per acre-foot in 1992.

Herbicides

Chemical treatment provides only temporary relief from chronic aquatic weed problems. In many instances, application is required at least twice per year. Therefore, the costs for chemical treatment are relatively high. An experimental study on East Twin Lake in Ohio concluded that weed harvesting was far more cost-effective than chemical treatment (Conyers and Cooke, 1982).

Although the method of chemical control has been extensively used, there has been relatively little documentation regarding environmental impacts. Although refuted by chemical manufacturers, there are still questions regarding the toxicity of certain chemicals to fish and other food chain organisms.

In the mid-west, the cost for one application of herbicide ranges from $140 to $310 per acre in 1984 dollars (EPA, 1990). The above costs include applicator's fees. Assuming a 5 percent inflation rate, this cost is estimated at $210 to $460 in 1992.

Benefits to the use of herbicides include:

1. Effective short-term management to rapidly reduce aquatic weeds for periods of weeks to months.

2. Application of herbicides is less time consuming than other weed control techniques.

Drawbacks to the use of herbicides include:

1. Vegetation is not removed from lake.

2. Plants die, decompose and release nutrients in the lake.

3. Dissolved oxygen concentrations are depleted by microbial decomposition. This may induce the release of nutrients from the sediments.

4. Algal blooms often occur as a result of increased nutrient levels.

5. Herbicides can be toxic to non-target species.

6. Some plant species may be tolerant to the herbicides.

7. Some herbicides are suspected to be mutagenic and carcinogenic.

8. The waiting period (10 days or more in most cases) following application of many herbicides interferes with recreational lake uses.

9. Unsightly conditions are often created.

Loon Lake

The use of chemical algicides and herbicides should be minimized and included only as part of an overall integrated approach to managing macrophytes.

Goose Lake

The use of chemical algicides and herbicides should be minimized and included only as part of an overall integrated approach to managing macrophytes.

5.1.6 Biological Controls

Biomanipulation (Shapiro, 1978) has been suggested as one method of controlling algal blooms in lakes. Theoretically, balancing phytoplankton, zooplankton, and fish populations will eliminate nuisance algal blooms.

The use of herbivorous fish, such as grass carp (*Ctenopharyngodon idella*), has been suggested as a lake management option for a number of lakes but does not appear feasible for Loon Lake. Grass carp prefer tender plant species, and would control wipe out the desirable species such as tapegrass (*Vallesnaria*) as well as the less desirable species, such as coontail (*Ceratophyllum*) and milfoil (*Myriophyllum*). Their ability to control waterlilies (*Nympheae* and *Nuphar*), however, is doubtful.

While triploid grass carp can not reproduce, they are still considered an exotic species by many states and their introduction is prohibited. Grass carp can not be brought into Indiana or released into public or private waters without a permit issued by the Director of the Division of Fish and Wildlife. The director may issue such permits for scientific or educational purposes only.

There are a number of negative effects associated with the introduction of grass carp. Grass carp may destroy desirable macrophyte species. Grazing by grass carp may reduce macrophyte biomass, but does not remove the nutrients from the lake. This may lead to increased eutrophication of a lake, with lower dissolved oxygen concentrations and increased algal blooms.

Loon Lake

The phytoplankton assemblage in Loon Lake would appear to limit the use of biomanipulation for controlling algal blooms. The dominant species, *Anabaena*, *Aphanizomenon* and *Microcystis*, are all expected to be unappetizing to zooplankton.

Due to regulatory restraints and the potential for negative impacts on water quality, the introduction of grass carp is not considered a viable management alternative for Loon Lake.

Goose Lake

The phytoplankton assemblage in Goose Lake would appear to limit the use of biomanipulation for controlling algal blooms. The dominant species, *Anabaena*, *Aphanizomenon* and *Microcystis*, are all expected to be unappetizing to zooplankton.

Due to regulatory restraints and the potential for negative impacts on water quality, the introduction of grass carp is not considered a viable management alternative for Goose Lake.

5.1.7 Physical Barriers

Physical sediment covering is another method which has been used to control macrophytes and sediment nutrient release. Researchers have experimented with various cover materials including sand, clay, synthetic sheeting and fly ash.

The primary advantages of sand is its lower material and application costs. However, sand has not been shown to provide either an effective physical or chemical barrier when used as a solitary treatment approach. Both macrophytes and nutrients are usually able to break through sand coverings. One apparently successful application of sand occurred in a lake where the nutrient-rich sediments were first excavated from the lake bottom.

A more promising candidate for a natural sealant might be clay. Although a full scale treatment with clay has not been reported, laboratory experiments indicated that a 5 cm layer of kalinite was effective in retarding phosphorus release for up to 140 days. However, the seal was eventually disrupted by gas formation in the sediments. In addition, it might be necessary to add a precipitant such as alum to remove colloidal clay particles from the water column. Also, the effect of rooted macrophytes on a clay layer has not been adequately tested. Overall, the use of clay or sand are not considered to be applicable to either Loon Lake or Goose Lake since these methods involve decreasing the depth of the lake.

The use of fly ash (a waste product from coal combustion) to control phosphorus release from sediments has also been tested. However, besides being susceptible to plants and gases in the same manner as sand and clay, the use of fly ash may cause adverse effects such as high pH, dissolved oxygen depletion, biological reduction of sulfate to sulfide, heavy metal accumulation and toxicity, and the physical clogging and crushing of organisms.

One of the more successful approaches for covering lake sediments where macrophytes are a factor has involved the use of synthetic sheeting. Sheeting can be installed by first lowering the water level, installing cover on ice surface and allowing it to sink during ice-out, or by wading out and installing it directly under water. The most commonly used sheeting material has been black polyethylene and nylon netting.

There have been several problems with the use of this material, including:

1. holes have to be placed in the sheeting to avoid the formation of gas pockets.

2. The sheeting was easily dislodged by currents.

3. The sand which is often used as an anchor can become enriched with new sediments and tends to again support weed growth after two to three years.

4. Polyethylene degrades rapidly in sunlight.

5. The sheeting may have severe impacts on the benthic community.

The most effective benthic covers are gas permeable screens, which are constructed of fiberglass, polypropylene, or nylon as opposed to those gas impermeable covers constructed of polyethylene or synthetic rubber materials. For the above screen materials, both fiberglass and polypropylene materials are generally the easiest to install and the most effective in controlling macrophytic growth (EPA, 1990).

The installation of benthic covers over large areas has only been successful demonstrated for several years. Once in place, sediments may accumulated on the barrier, thereby allow plant fragments to re-establish. Therefore, screens must removed and periodically cleaned, possibly every 2 to 3 years. For localized control, such as around docks, benthic barriers are routinely installed in early spring and removed in the fall. While this introduces a winter storage problem, it prevents the re-establishment of macrophytes.

Loon Lake

Benthic barriers may be applied as part of an integrated aquatic plant management plan for Loon Lake. Where plant growth is dense, benthic barriers could be installed from individual docks to the edge of the littoral zone (the region extending from the lake's shoreline to open water), thereby increasing boat access to the open water and reducing the use of aquatic herbicides. Of the wide-variety of materials on the market, fiberglass or polypropylene materials should be used over other barriers because these materials are gas permeable and are easier to install.

Assuming an individual dock requires 400 square feet (20 by 20 feet) of lake bottom to be covered, polypropylene and fiberglass netting would cost approximately $40 and $120, respectively. The above costs do not include shipping and installation, and any additional materials, such as benthic anchors.

Goose Lake

Benthic barriers may be applied as part of an integrated aquatic plant management plan for Goose Lake. Where plant growth is dense, benthic barriers could be installed from individual docks to the edge of the littoral zone (the region extending from the lake's shoreline to open water), thereby increasing boat access to the open water and reducing the use of aquatic herbicides. Of the wide-variety of materials on the market, fiberglass or polypropylene materials should be used over other barriers because these materials are gas permeable and are easier to install.

Assuming an individual dock requires 400 square feet (20 by 20 feet) of lake bottom to be covered, polypropylene and fiberglass netting would cost approximately $40 and $120, respectively. The above costs do not include shipping and installation, and any additional materials, such as benthic anchors.

5.1.8 Nutrient Inactivation

Nutrient inactivation usually consists of adding aluminum salts (aluminum sulfate and/or sodium aluminate) to produce an aluminum hydroxide floc which forms a chemical bond with phosphorus. This procedure is most effective in providing long-term improvements in water quality in deep lakes over 50 acres in size with a low flushing rate and where watershed inputs of phosphorus have been minimized. Since phosphorus-rich sediments will release phosphorus in the water column under anoxic conditions, such as in Loon Lake and Goose Lake, water quality problems can continue in a lake long after watershed controls are implemented. By applying aluminum salts within the hypolimnion, a chemical barrier is established which can provide continuous control of phosphorus.

Connor and Martin (1989) and Cooke, et al. (1986) provide an excellent summary of the effects and costs of using aluminum salts (alum) to inactivate sediment phosphorus. Assuming that watershed phosphorus loading has been minimized, this management technique can provide long-term improvements in water quality with minimal negative environmental impacts. Based on the treatment costs for six New England lakes, the average cost was approximately $1,372 per hectare at a mean aluminum dosage of 28 grams of aluminum per cubic meter (Connor and Martin, 1989). In recent years, the trend has been towards using higher application dosages ranging from 40 to 45 grams of aluminum per cubic meter. Due to advancements in application technologies, alum treatment costs in the mid-1980's have been further reduced to $1,306 per hectare at a dosage of 40-45 grams of aluminum per cubic meter. At an annual inflation rate of five percent, this would be equivalent to $1,838 per hectare in 1992.

The actual aluminum dosage is lake specific and largely depends on the results from jar tests, which are performed in the laboratory. For the Loon and Goose Lakes study, jar tests were beyond the scope of this project. Therefore Loon and Goose Lakes, the costs for hypolimnetic alum treatments are only intended as "estimated" values and are based on the above cost of $1,838 per hectare at a dosage of 40-45 grams of aluminum per cubic meter.

For in-lake alum treatment to be cost-effective, a lake should have a long hydraulic residence time (generally greater than 0.5 years), high sediment phosphorus concentrations, high hypolimnetic phosphorus concentrations, high summer phytoplankton levels, and low total suspended and phosphorus loadings from its surrounding watershed. In the following paragraphs, the estimated cost for alum treatment for each lake are discussed.

Loon Lake

Loon Lake has a hypolimnetic area of approximately 146 acres (59 hectares). Assuming an average alum cost of $1,838 per hectare at a dosage of 40-45 grams of aluminum per cubic meter, the estimated cost to treat Loon Lake with alum is $108,500.

At the present time, it is not likely that this technique will have long-term effectiveness and be cost-effective for Loon Lake unless watershed loading is reduced significantly. The long-term effectiveness may be further limited by the relatively high flushing rate of Loon Lake. Once nutrient and suspended solid loadings from the watershed are reduced, alum treatment should be reevaluated for Loon Lake.

Goose Lake

Goose Lake has a hypolimnetic area of approximately 55 acres (22 hectares). Assuming an average alum cost of $1,838 per hectare at a dosage of 40-45 grams of aluminum per cubic meter, the estimated cost to treat Goose Lake with alum is $40,500.

At the present time, it is not likely that this technique will have long-term effectiveness and be cost-effective for Goose Lake unless watershed loading is reduced significantly. Once nutrient and suspended solid loadings from the watershed are reduced, alum treatment should be reevaluated for Goose Lake.

5.1.9 Dilution/Flushing

Dilution and flushing can improve water quality in eutrophic lakes by diluting the amount of phosphorus in the lake while increasing the flushing of algae from the lake. This technique works best in lakes that have a low flushing rate and is most cost effective when a large quantity of low-nutrient water is available. In most cases, the water supply for dilution and flushing is accomplished by diversion of water from a nearby river, although the use of wells may also be used.

Loon Lake

It has been estimated that even if the flushing rate of Loon Lake was doubled by adding 6.1 million gallons per day of water containing only 0.001 mg/L of phosphorus, the water quality would not improve to mesotrophic levels, due to high pollutant loads from non-point sources within the watershed. Therefore, dilution and flushing is not a viable management technique for Loon Lake.

Goose Lake

It has been estimated that even if the flushing rate of Goose Lake was doubled by adding 0.9 million gallons per day of water containing only 0.001 mg/L of phosphorus, the water quality would not improve to mesotrophic levels, due to high pollutant loads from non-point sources within the watershed. Therefore, dilution and flushing is not a viable management technique for Goose Lake.

5.2 Watershed Management Alternatives: Agricultural Best Management Practices

Nonpoint source pollution from agricultural runoff is a significant source of phosphorus, nitrogen, and sediment in the Loon Lake watershed. Approximately 87 percent of the phosphorus load, 81 percent of the nitrogen load, and 98 percent of the sediment load originates with agricultural runoff. The same is true of the Goose Lake watershed, where approximately 80 percent of the phosphorus load, 64 percent of the nitrogen load, and nearly 100 percent of the sediment load originates with agricultural runoff. A number of agricultural best management practices (BMP's), such as conservation tillage, cover cropping, critical area planting, terraces, farmland management, fencing, agricultural waste storage structures, filter strips, grassed waterways, and impoundment ponds can be implemented in the Loon and Goose Lake watershed to control pollutant loadings from agricultural runoff. These BMP's are discussed in detail below.

5.2.1 Conservation Tillage

Conservation tillage applies to crop tillage methods used to control the amount of erosion from crop fields. It is accomplished by leaving a certain percentage of the crop residue on the field at all times. Stormwater runoff can be reduced by retaining water on the fields and infiltration can be increased due to slower runoff velocities.

The most common conservation tillage practice is no-tillage or zero tillage. No-till farming involves soil preparation and planting that are accomplished in one operation with specialized farm equipment. This results in limited soil disturbance and leaves most crop residues on the soil surface. Planting is normally done in narrow slots opened by a fluted coulter or double-disk opener. Soil infiltration rates of the area are increased by maintaining a plant canopy or a mulch of plant residues on the surface for the entire year.

However, soil compaction and reduction of evaporation from the surface due to the residues may lead to increases in runoff.

Other conservation tillage practices such as ridge planting, strip tillage, and plow planting are less common than no-tillage. Typically these methods require specialized soil and cropping conditions to be practical. Some of the conservation tillage methods may also decrease runoff volume by allowing significant amounts of runoff to infiltrate into the soil. The infiltration capacity is dependent on the amount of soil compaction in the undisturbed areas of the field and the amount of crop residues that are left exposed. High soil compaction inhibits infiltration whereas exposed crop residues absorb the water and retain it on site until it evaporates.

Additional benefits of conservation tillage include less labor per acre, lower equipment costs, and reduced fuel costs. Disadvantages of conservation tillage include increased use of herbicides, soil compaction, increased management requirements, and lower soil temperatures in spring caused by heavy mulch residue. Concentrations of nitrate in runoff water from conservation tilled fields are typically higher than concentrations from conventionally tilled fields. This is not necessarily a disadvantage since less runoff occurs from conservation tilled fields. The concentration of available phosphorus in eroded soils is higher with conservation tillage than with conventional tillage. Again, this is not necessarily a disadvantage since less soil erosion occurs when conservation tillage practices are employed.

The effectiveness of no-till farming is considerable. A comprehensive study performed in Georgia indicated that runoff can be reduced by 47 percent with the use of no-till farming. Soil loss can be reduced by 91 to 98 percent with the use of no-till farming compared to convention tillage (North Carolina Agricultural Extension Service, 1982). Conservation tillage can reduce pesticide and phosphorus transport by 40 to 90 percent for conservation tillage and 50 to 95 percent for no-till (EPA, 1987). Increased reliance on pesticides typically associated with conservation tillage can be avoided by implementing an integrated pest management program. Using conservation tillage without an appropriate pesticide and fertilizer management plan is not considered an acceptable BMP (EPA, 1987).

Loon Lake

The use of conservation tillage, particularly no-till methods, is recommended for the watershed, providing that an integrated pesticide/fertilizer management plan is also implemented to avoid increased runoff of these chemicals.

Goose Lake

The use of conservation tillage, particularly no-till methods, is recommended for the watershed, providing that an integrated pesticide/fertilizer management plan is also implemented to avoid increased runoff of these chemicals.

5.2.2 Integrated Pest Management

Integrated pest management is a combination of traditional pest control methods, such as crop rotation and pesticides, with a careful monitoring of the pests to improve the efficiency of the pesticides and other controls. The amount of pesticides applied at any one time can be minimized by targeting specific pests at vulnerable points in their life cycle. The EPA/USDA Rural Clean Water program is emphasizing the need for pesticide and fertilizer management to limit groundwater contamination. Reductions in pollutant loadings range from 20 percent up to 90 percent (EPA, 1987). Since pesticides and fertilizers are applied at their most effective times and quantities, this BMP can save money in both labor and materials.

Loon Lake

Integrated pest management should be implemented along with any conservation tillage activities within the watershed.

Goose Lake

Integrated pest management should be implemented along with any conservation tillage activities within the watershed.

5.2.3 Cover Cropping

Cover cropping involves planting and growing cover and green manure crops. Cover and green manure crops are crops of close-growing grasses, legumes (clover), or small grain planted in a fallow field and plowed into the ground before the next row of crop is planted. This technique is used to control erosion during periods when the major crops do not furnish cover. In addition to erosion control, residual nitrogen from legume cover crops enhances the soil for the major commercial crops and should be considered when calculating the nitrogen requirements of these crops planted later.

The cover crop can be seeded after harvesting the major crop by light plowing or it can be seeded prior to cultivation of the major crop without additional seedbed preparation. The cover crop should be protected from grazing until it is well established and from weeds by chemical or mechanical methods as needed. Cover crops are most beneficial to farm practices that leave bare soil following harvesting.

Loon Lake

In the Loon Lake watershed, planting small grain as cover or harvestable crops between corn and soybean crops would be applicable and beneficial to most of the farms in the area. Retention of moisture, nutrients and use of the harvested crop would probably more than offset costs of implementation.

Goose Lake

In the Goose Lake watershed, planting small grain as cover or harvestable crops between corn and soybean crops would be applicable and beneficial to most of the farms in the area. Retention of moisture, nutrients and use of the harvested crop would probably more than offset costs of implementation.

5.2.4 Critical Area Planting

Critical area planting involves planting vegetation on critical areas to stabilize the soil and promote stormwater infiltration, thereby reducing damage from sediment erosion and excessive runoff to downstream areas. Critical areas can be sediment-producing, highly erodible, or severely eroded areas where vegetation is difficult to establish with usual seeding or planting methods.

The selection of vegetation and the use of mulching materials immediately after seeding is of special concern. Jute and excelsior matting and mulching can be used to protect soil from erosion during the period of vegetative establishment when plants are most sensitive to environmental conditions. To reinforce areas designated for planting, bank stabilization structures can be used.

Maintenance of critical area planting includes periodic inspection of seeded areas for failures. Repairs should be made as needed. If the stand is more than sixty percent damaged, the planting area should be re-established using the original planting criteria.

Loon Lake

Permanent vegetation should be established on areas within the watershed that are subject to severe erosion.

Goose Lake

Permanent vegetation should be established on areas within the watershed that are subject to severe erosion.

5.2.5 Terraces

A terrace is an earth embankment, ridge or channel constructed across a slope at a suitable location to intercept runoff water and control erosion. Generally terraces are considered supporting practices to use in conjunction with contouring, stripcropping and reduced tillage methods. Terracing has been shown to be highly effective in trapping sediment and reducing erosion. The effectiveness of terracing is not as good for reducing the loss of nutrients and soil from surface runoff. Subsurface nitrogen losses may increase.

A terrace can be constructed across a slope with a supporting ridge on the lower side. The use of terraces is usually not applicable below high sediment producing areas without supplementary control measures. Any sediment build-up that does occur should be removed on an as-needed basis.

The effectiveness of terraces for reducing sediment loss ranges from 50 to 98 percent and costs are approximately $2/ft.

Loon Lake

There are only a few areas within the Loon Lake watershed where slopes are greater than 8 percent. Therefore, terracing will have limited applicability as a BMP for the area but should be considered where applicable.

Goose Lake

There are only a few areas within the Goose Lake watershed where slopes are greater than 8 percent. Therefore, terracing will have limited applicability as a BMP for the area but should be considered where applicable.

5.2.6 Grassed Waterways

Grassed waterways are designed to facilitate the safe disposal and transmission of surface runoff. Grassed waterways apply to both natural and constructed drainage channels. Grassed waterways may prevent 60 to 80 percent of the suspended particles in surface runoff from reaching nearby streams. Grassed waterways should be used in conjunction with other BMP's such as conservation tillage and terraces.

Constructed grassed waterways are generally shaped or graded by heavy equipment and are usually over ten feet wide at the top of the channel. Vegetation cover is usually a variety of grass or legume compatible with existing species in the area. These channels should be protected from grazing, fire and insects and should not be used as farm roads. Maintenance consists of mowing the grass and spraying if weed control is needed. If necessary, cuttings should be removed to prevent transport to nearby streams during storm events. All seeded areas should be inspected occasionally for needed repairs. Also, any sediment build-up that significantly reduces the capacity of the channel should be removed.

Loon Lake

Grassed waterways should be established in all drainage swales within the watershed.

Goose Lake

Grassed waterways should be established in all drainage swales within the watershed.

5.2.7 Grade Stabilization Structures

Soil in areas subject to heavy erosional forces, such as the outlet of a grassed waterway or a steep area which will not support vegetative cover, can be stabilized with a structure such as riprap. This is an effective method for treating small problem areas unsuitable for other stabilization methods. Construction cost for grade stabilization is approximately $1,000 per structure.

Loon Lake

Grade stabilization structures should be established where applicable within the watershed.

Goose Lake

Grade stabilization structures should be established where applicable within the watershed.

5.2.8 Farmland Management

Farmland management incorporates several practices which discourage accelerated erosion at the farm site. The first farmland management practice is commonly referred to as pasture and hayland planting. Pasture and hayland planting involves the proper planting techniques to establish long-term stands of adapted species of perennial and biennial forage plants. The primary purpose of pasture and hayland planting is erosion control. An additional benefit could be the production of a high quality forage crop. Proper planting measures involve the adequacy and timing of lime and fertilizer application; determination of a particular area's seedbed preparation needs, seed mixtures, seeding rates, and weed control.

In addition to special planting techniques there are also general pasture and hayland management techniques. Pasture and hayland management involves the proper treatment and use of pasture and hayland. Proper management involves the use of adapted species of grasses, time of harvest, state of plant growth and height to which plants are cut of grazed, and the control of weeds, diseases and insects. Of particular importance is establishment of grazing plans. Grazing plans should be developed to include schedules for moving animals into and out of the pasture as well as for maintenance of the pasture. Uniform, complete cover, and vigorous pasture growth are essential for control of erosion and subsequent nutrient loss. Adequate pasture facilities should be provided, including waters, shade and mineral feeders. These facilities should be periodically moved to prevent overuse in any one area. Streams, ponds, and lakes should be fenced to limit animal access.

Another farmland management practice is the control of livestock watering facilities. The development and protection of springs can be used as water supply sources of farms. Spring development involves excavation, cleaning, and capping of waterways to convey and distribute water to livestock at several locations in the farmyard and pastures. This technique distributes grazing to several points rather than concentrating it in one area. Concentrated grazing can result in overgrazing which in turn leads to accelerated erosion. Developments should be confined to springs or seepage areas that are capable of providing a dependable supply of suitable water during the planned period of use. Maintenance includes the periodic removal of sediment from spring boxes.

Loon Lake

The appropriate farmland management practices should be established within the watershed.

Goose Lake

The appropriate farmland management practices should be established within the watershed.

5.2.9 Fencing

Fencing involves enclosing and dividing an area of land with a permanent structure that serves as a barrier to animals and people. The primary purpose of fencing is to control erosion by protecting sensitive areas, particularly watercourses, from the disturbance of grazing or public access, by subdividing designated grazing areas for a planned grazing system and by protecting new seedlings and plantings from grazing until they are well established. Fencing may also be a source pollution control by preventing livestock from depositing their wastes in natural watercourses.

Fencing controls streambank erosion by preventing both the physical destruction of the bank and the denuding of streambank vegetation from grazing animals. The use of filter strips between fences and the watercourses can increase the effectiveness of fencing. Fences for this purpose are not to be temporary such as electric fences. Depending on the type of animal to be restricted, the permanent fence can be woven wire, barbed wire, or high tension wire. Fences should be periodically inspected to check for broken or disconnected wire, loose staples and loose or deteriorated post or brace members.

Loon Lake

Fences should be established where livestock have direct access to surface water within the watershed.

Goose Lake

Fences should be established where livestock have direct access to surface water within the watershed.

5.2.10 Agricultural Waste Storage Structures

An agricultural waste storage structure can be either an above-ground fabricated structure or an excavated pond. The above-ground fabricated structure can be either a holding tank or a manure stacking facility designed to temporarily store nontoxic agricultural and animal wastes. The primary purpose of agricultural waste storage structures is to reduce contamination of natural watercourses by source pollution control of liquid and solid wastes. Wastes can be disposed of by controlled application to cropland. Animal wastes supply soils with nutrients and soil tilth. Runoff rates are reduced and soil infiltration rates are increased with the application of animal wastes. Manure should not be applied when the ground is frozen or there is snow on the ground.

Manure stacking facilities that are used for solid waste may be open or roofed. Manure stacking facilities can be made of reinforced concrete, reinforced concrete block, precast panels, or treated tongue and groove lumber. Holding tank facilities for liquid and slurry wastes may be open or covered. Holding tanks may be located indoors, beneath slotted floors. Holding tanks can be made of cast-in-place reinforced concrete or fabricated steel with fused glass or plastic coatings.

Both holding tanks and stacking facilities should be emptied in accordance with the overall waste management plan for land application. If the holding tanks are located outdoors and are not covered, a grass waterway should be constructed downslope of the tanks to prevent surface runoff from reaching a stream or drainage channel.

A waste storage pond is an impoundment constructed by excavation or earthfill for temporary storage of nontoxic agricultural and animal wastes. When polluted runoff is stored, accumulated liquids are removed from the pond promptly after settling to ensure that sufficient capacity is available to store runoff from subsequent storms. Extraneous surface runoff should be prevented from entering the pond. The pond should be located as near to the source of waste or polluted runoff as possible. Soils under the pond should be of low to moderate permeability. Where self-sealing is not probable, the pond should be sealed by mechanical treatment or by using an impermeable membrane. Accumulated wastes should be properly disposed of as discussed above for fabricated structures. Waste storage ponds should be properly maintained including periodic inspection and clearing of inlets.

Agricultural waste storage structures can result in significant nutrient reductions because the wastes treated by these structures contains nutrients in mobile forms. In the Loon Lake watershed there are a number of livestock operations which probably need some type of waste storage structure. Construction costs can run from $5,000 to $15,000 depending on volume and treatment requirements.

Loon Lake

Agricultural waste storage structures are recommended at all livestock operations within the watershed.

Goose Lake

Agricultural waste storage structures are recommended at all livestock operations within the watershed.

5.2.11 Agricultural Waste Management

Manure is a resource that should be used and managed wisely to increase crop yields and control pollution. In normal farming operation manure application provides nutrients for plant growth, improves soil tilth, and helps develop beneficial soil organisms. The use of manure as a fertilizer also decreases the erosion potential of the soil and promotes infiltration and retention of water in soil. The use of manure can reduce soil loss from sloping land by 58 to 80 percent. (North Carolina Agricultural Extension Service, 1982)

A manure management plan should be adopted for individual farms. The plan should include methods to conserve nutrients in the manure while it is being stored, to determine appropriate application rates, to determine appropriate time of application, and to determine the method of application. Methods of application typically include daily spreading, storage and periodic spreading, and subsurface injection.

Loon Lake

A manure management plan should be established for each farm within the watershed.

Goose Lake

A manure management plan should be established for each farm within the watershed.

5.2.12 Buffer Strip

Buffer strips are vegetated areas which intercept storm runoff, reduce runoff velocities, and filter out runoff contaminants. Although filter strips are similar to grassed waterways, they are primarily used along surface waters which are adjacent to urban developments, agricultural fields, and logging areas.

Successful application of buffer strips to urban developments and agricultural fields requires consideration of natural drainage patterns, steepness of slopes, soil conditions, selection of proper grass cover, filter width, sediment size distribution, and proper maintenance. All of these factors affect pollutant removals, which can range from 30 to over 95%, depending on local conditions.

Water tolerant species of vegetative cover (reed canary grass, tall fescue, Kentucky bluegrass, and white clover) should be used to maintain high infiltration rates. The type of filter strip depends upon land capability, uses of the strip, types of adjacent land use, kinds of wildlife desired, personal preferences of the landowner, and availability of planting stock or seed. Filter strips should be established at the perimeter of disturbed or impervious areas to intercept sheet flows of surface runoff. These grass buffer strips will slow runoff flow to settle particulate contaminants and encourage infiltration. Periodic inspections are necessary and thatch should be periodically removed. A recent study has shown that vegetative buffer strips with established woody undergrowth may be more effective at reducing pollutants in runoff than grass buffer strips, but presents much lower removal efficiencies in all cases (Dennis, et al., 1989).

The Classified Filter Strips Act (HEA 1604), which was passed by the Indiana General Assembly in 1991, provides tax abatement incentives for those individual who establish vegetative filter strips adjacent to ditches, creeks, rivers, wetlands or lakes. By establishing a vegetative filter strip, landowners may have those land parcels assessed at $1 per acre for property taxation purposes. Under this act, filter strips must be between 20 and 75 feet wide. For more information regarding this program, contact the county surveyor.

Loon Lake

In the Loon Lake watershed, buffer strips would be an effective method to use in agricultural areas suffering from turn row erosion and along streams and ditches. Runoff in a field can travel along individual rows, concentrating in the areas at the ends of the rows where the plow made a sharp turn. Much of the farmed land is presently plowed right up to the ditches. Approximately 10 feet of buffer may remove around 80 percent of the total solids from runoff (EPA, 1987).

Goose Lake

In the Goose Lake watershed, buffer strips would be an effective method to use in agricultural areas suffering from turn row erosion and along streams and ditches. Runoff in a field can travel along individual rows, concentrating in the areas at the ends of the rows where the plow made a sharp turn. Much of the farmed land is presently plowed right up to the ditches. Approximately 10 feet of buffer may remove around 80 percent of the total solids from runoff (EPA, 1987).

5.3 Watershed Management Alternatives: Wastewater

5.3.1 Wastewater Treatment Facility

Loon Lake

Septic systems account for 12 percent of the phosphorus loading to Loon Lake. While this is a relatively small percentage of the annual load, the nutrients are delivered directly to the shallow waters of the lake, where macrophyte growth is a problem. The only way to eliminate loading from septic systems is to install a wastewater collection and treatment system, which is an expensive alternative to address 12 percent of the problem.

Based on the number of homes and people around Loon Lake used to calculate septic system loading and assuming a water usage of 75 gallons per capita per day, it is estimated that a 60,000 gallon per day wastewater treatment facility would be needed. If a stream discharge would not be feasible, an alternative to stream discharge is land application such as spray irrigation, where treated wastewater is applied to a parcel of land through a sprinkler system. Wastewater can only be sprayed during the warmer half of the year at an application rate determined by soil suitability. The remaining time of the year, wastewater must be stored in a lagoon. Storage requirements will be less than spray requirements, since a certain percentage of the lake users are only present during the summer months. Assuming an application rate of 0.5 inches per acre per week and a 180 day spray season, a spray irrigation wastewater treatment system would require 6.2 acres for storage (4.9 acres of lagoon and 1.3 acres for berms) and 40 acres for spraying (29.5 acres of spray field and 10.4 acres for a 100 foot buffer around the spray field).

The estimated cost for a 60,000 gallon per day wastewater treatment facility could range from $500,000 to $600,000 and does not include the acquisition of land, engineering design work, surveying work, materials for the sewage collection system (sewer transmission lines), and the installation of the sewage collection system. The above cost is based on the discharge of treated wastewater effluent to a nearby stream. If the spray irrigation option is used, the above cost is expected to increase.

Goose Lake

Septic systems account for 21 percent of the phosphorus loading to Goose Lake. This is a relatively large percentage of the annual load, and the nutrients are delivered directly to the shallow waters of the lake, where macrophyte growth is a problem. The only way to eliminate loading from septic systems is to install a wastewater collection and treatment system, which is an expensive alternative.

Based on the number of homes and people around Goose Lake used to calculate septic system loading and assuming a water usage of 75 gallons per capita per day, it is estimated that a 22,000 gallon per day wastewater treatment facility would be needed. A standard wastewater treatment system with a stream discharge would not be an acceptable alternative, since even the most advanced treatment plants would discharge relatively high levels of phosphorus into the stream. This phosphorus would be in a form preferred by plants and algae, and the discharge would have to be to Winters Ditch, which flows into Loon Lake. An alternative to stream discharge is land application such as spray irrigation, where treated wastewater is applied to a parcel of land through a sprinkler system.

Wastewater can only be sprayed during the warmer half of the year at an application rate determined by soil suitability. The remaining time of the year, wastewater must be stored in a lagoon. Storage requirements will be less than spray requirements, since a certain percentage of the lake users are only present during the summer months. Assuming an application rate of 0.5 inches per acre per week and a 180 day spray season, a spray irrigation wastewater treatment system would require 5.9 acres for storage (4.7 acres of lagoon and 1.2 acres for berms) and 14.6 acres for spraying (8.9 acres of spray field and 5.7 acres for a 100 foot buffer around the spray field).

The estimated cost for a 22,000 gallon per day wastewater treatment facility could range from $550,000 to $650,000 and does not include the acquisition of land, engineering design work, surveying work, materials for the sewage collection system (sewer transmission lines), and the installation of the sewage collection system. The above cost is based on the application of treated wastewater effluent to nearby lands via a sprinkler system.

5.3.2 Septic System Management

There are a number of things that homeowners can do to minimize the effects of septic systems on water quality. Examples of septic system Do's and Don't's are as follows:

DO NOT:

1. Add excessive amounts of harsh chemicals to the system. Normal household chemicals in normal amounts will not hurt the system.

2. Physically damage the system by driving over the units with heavy vehicles, digging up the system for other utility lines, etc.

3. Connect a garbage grinder to the system.

4. Pour cooking oil, fat, motor oil, etc. down the drain.

5. Put disposable diapers, sanitary napkins, tampons or other material containing non-biodegradable substances into the system.

6. Use excessive amounts of water in the home.

7. Bathe and wash clothes at the same time, or do repeated loads of washing one after the other.

8. Plant trees over or near the absorption area. Roots will enter and clog the pipes.

DO:

1. Protect the system from surface drainage. Divert downspouts and surface water away from the system.

2. Check scum and sludge levels in a SEPTIC TANK at least once each year and pump if necessary.

3. Check for proper operation of AEROBIC TANKS weekly following manufacturers instructions. It is extremely important to make sure that all components are functioning properly and that air is being continually supplied to the unit. Do not shut off aerobic tanks for vacations or other extended absences from home.

4. Protect the system and surrounding area from damage. This is especially important for elevated sand mound systems. Keep grass cut to allow sun heat to evaporate moisture.

5. Keep a record of the location and dimensions of the system. If purchasing, obtain the location and other pertinent information from the previous owner.

6. Install water saving devices.

7. Operate washing machine/dishwasher with full loads only.

Attempts should be made to identify inadequate or failing systems. Septic leachate detectors may be used to identify malfunctioning septic systems adjacent to Loon Lake. The use of septic leachate detectors, however, is not recognized by the Environmental Protection Agency as a valid technique for identifying failing septic systems. Dye studies can also be performed to determine if there are obvious malfunctions. Once a failure has been identified there are several options to correct the problem. The septic system can be replaced, modified, or the septage can be removed more frequently. If problems occur in clusters, community systems can be installed. The ultimate solution to eliminate failing septic systems is to install a sewage collection system and a wastewater treatment plant.

Loon Lake

The lake association should work with the county health inspector to establish a septic system maintenance and inspection program. Failing systems should be identified and repaired.

Goose Lake

The lake association should work with the county health inspector to establish a septic system maintenance and inspection program. Failing systems should be identified and repaired.

5.4 Watershed Management Alternatives: Impoundment Ponds and Water Control Structures

5.4.1 Impoundment Ponds

Surface water impoundments can be used to protect downstream areas from flooding, stream channel erosion, and water quality degradation from increased runoff. The basic objective is to detain stormwater and release it at a controlled rate. There are two types of impoundments. Detention basins are "dry" impoundments that temporarily store runoff and then release it to downstream surface water channels at a controlled rate. Retention basins, or ponds, are "wet" impoundments that provide "permanent" storage and release runoff waters through infiltration and evaporation.

Applicability of impoundments is dependent upon the availability of sufficient land to provide the necessary impoundment volume. However, this usually is true in densely urbanized areas and may not be a concern in the agricultural areas of the Loon Lake watershed.

Impoundment ponds may be designed to maximize their effect on water quality. Upgrading of water quality is primarily achieved through sedimentation but chemical transformation and biological uptake also occurs while runoff is detained in the basin.

Impoundments can be designed for individual site control or to control runoff from multiple development sites or watershed areas. In some cases considerable economies of scale can be achieved through utilization of centralized impoundments servicing large areas. However, the need for upstream channel protection above these impoundments can reduce the anticipated savings. In areas where the anticipated nonpoint source pollutant load is expected to be particularly heavy, multiple ponds designed to perform in series may be more effective in controlling water quality. Under these circumstances, an upper pond may serve as a settling basin that releases higher quality water into a lower pond.

Impoundment ponds can trap significant quantities of sediments (65 to 90%) and nutrients (30 to 60%). However, the efficiency of the ponds depends on the runoff characteristics. Better treatment efficiencies have been observed for fifty year record storms. Impoundment ponds should be used with other erosion control practices so that the basins do not fill up with sediment too rapidly and lose their efficiency.

Maintenance of the impoundment areas is essential. A formal maintenance plan should be formulated and should include:

1. Routine inspection and cleaning of pipe inlets and outlets for accumulated sediment and debris.

2. Critical area stabilization and vegetative control.

3. Measures to offset the production of fast-breeding insects, as necessary.

4. Periodic inspection by a qualified professional to ensure that impoundments remain structurally sound and hydraulically efficient.

This method of erosion control is potentially beneficial in several areas within the Loon and Goose Lake watershed. There are benefits other than erosion control which can be realized from installation of impoundment ponds. The pond itself enhances the aesthetic value of the immediate area. The water may draw nearby geese and other waterfowl providing recreational hunting opportunities. Under optimum conditions, the best reductions possible using sedimentation basins would be 90 percent of the total suspended solids and 60 percent of the total phosphorus, based on the results of the National Urban Runoff Program (Driscoll, 1983). This would require a 1 acre basin, approximately 3.5 feet deep, for every ¼ square mile, or 3.84 acres of basin for every square mile of drainage area.

The most effective placement of basins would be to site a number of small basins with small drainage areas throughout the watershed, concentrating on areas identified as having the highest potential for pollutant runoff. Construction costs for a small impoundment pond can run from $750 to $10,000, depending on the drainage area involved.

Loon Lake

An impoundment pond may be constructed in a wetland area where Friskney Ditch drains into Loon Lake. The direct drainage area of Friskney Ditch is approximately 2.9 square miles and accounts for more than 30 percent of the lands that drain into Loon Lake. Based on the sizing requirements presented by Driscoll (1983), the impondment should be at a minimum size of 12 acres at a depth of 3.5 feet. The estimated cost of a 12 basin created by berming and excavation is $460,000, based on similar estimates for smaller basins multiplied by the increased area of this basin. This cost includes design and construction, but does not include land acquisition or permit application fees. Costs may actually be lower based upon a detailed design study.

In addition to the recommended impoundment for Friskney Ditch, impoundment ponds should be considered in areas where other watershed BMP's, such as terracing, can not be implemented. The ponds should be used in conjunction with other applicable BMP's such as grassed waterways and buffer strips. Periodic removal of the accumulated sediments would be required. Based on the predicted removal rates and the estimated watershed loading in Section 4.0, a one acre basin sized according to the above formula would accumulate 67,000 pounds of sediment annually.

Goose Lake

The use of impoundment ponds should be considered in areas where other watershed BMP's, such as terracing, can not be implemented. The ponds should be used in conjunction with other applicable BMP's such as grassed waterways and buffer strips.

Periodic removal of the accumulated sediments would be required. Based on the predicted removal rates and the estimated watershed loading in Section 4.0, a one acre basin sized according to the above formula would accumulate 77,000 pounds of sediment annually.

5.4.2 Water Control Structures

A series of check dams can be constructed in existing drainage ditches in order to manage water level according to need. During periods of high runoff, small dams would create small detention areas and can provide some measure of flood control and check the transport of sediment, along with associated nutrients and bacteria. In winter, maintenance of water in ditches would encourage denitrification (conversion of nitrate and nitrite to N_2), reducing the nutrient load to streams and lakes, although denitrification would proceed at a slower rate during the winter months because of the lower temperatures.

Loon Lake

The use of check dams should be considered as a means of reducing the downstream flow of nutrients and sediments. Water control structures should be used in conjunction with grassed waterways and buffer strips.

Goose Lake

The use of check dams should be considered as a means of reducing the downstream flow of nutrients and sediments. Water control structures should be used in conjunction with grassed waterways and buffer strips.

5.4.3 Tile Drains

Wherever possible, tile drains should be routed away from direct discharge to the lakes or their tributaries. Tiles should discharge into water quality basins or created wetlands. Surface drains should be wrapped in filter fabric and protected by rip-rap.

5.5 Watershed Management Alternatives: Streambank and Roadway Stabilization

5.5.1 Stream Bank Erosion Control

Most of the stream banks and road shoulders in the Loon and Goose Lakes watershed are gently sloped and vegetated. However for those areas along streams and roadways exhibiting signs of severe soil erosion, streambank and roadway stabilization practices should be implemented.

Although it was beyond the scope of this study to identify specific streambank erosion problems, stream bank erosion is often a significant source of the sediments and nutrients that enter a lake.

Stream bank erosion can be corrected in various ways: (1) by reducing the amount and velocity of water in the stream; (2) by relatively high cost structural controls such as rip-rap and gabions; and (3) by relatively low-cost vegetative controls such as willow twigs, grasses, shrubs, or ornamental wetland plants. The unit costs for rip-rap and gabions are estimated at $28 per cubic yard and $26 per square yard (R.S. Means Company, Inc. 1991). For these costs, rip-rap consists of random broken stone and gabions are constructed of galvanized steel mesh mats that are filled with 6 inches of stone. The above costs include equipment and labor costs to place stone. These costs do not include hauling costs for above, permit preparation fees, permit fees, and equipment and labor costs for any excavation or grading work prior to placing stone.

Reducing the amount and velocity of water in the stream is not usually practical since existing upstream conditions dictate the present storm flow regime. However, controls can keep the existing amount and velocity of water from increasing. Creation and implementation of a Runoff Control Ordinance will minimize the increase in the amount and velocity of storm flow associated with new development, resulting in little or no increase in streambank erosion.

Loon Lake

All stream banks exhibiting excessive soil erosion should be identified and classified according to the degree of erosion, such as slight, moderate, or severe. After ranking all stream banks impacted by erosion, vegetative or structural controls should be implemented.

Structural stream bank erosion controls such as rip-rap or gabions should only be implemented in severe problem areas where low-cost vegetation controls cannot be used. Low-cost vegetative controls should be used wherever practical to control moderate and severe stream bank erosion. Vegetative controls can often be planted by volunteers such as Boy Scouts and Girl Scouts. Use of volunteers enhances the benefits by adding educational and publicity aspects to the program. When stabilization measures are proposed in a legal drain, both the county surveyor and the county drainage board should be contacted.

Detailed design suggestions for stream bank and shoreline protection are presented in the Soil Conservation Service Technical Guide under Standards and Specifications No. 580 (1989). The county conservation districts can provide valuable technical assistance in planning shoreline stabilization projects. When streambank stabilization is proposed for legal drains in the state of Indiana, the county surveyor and the county drainage board should be contacted.

Goose Lake

All stream banks exhibiting excessive soil erosion should be identified and classified according to the degree of erosion, such as slight, moderate, or severe. After ranking all stream banks impacted by erosion, vegetative or structural controls should be implemented.

Structural stream bank erosion controls such as rip-rap or gabions should only be implemented in severe problem areas where low-cost vegetation controls cannot be used. Low-cost vegetative controls should be used wherever practical to control moderate and severe stream bank erosion. Vegetative controls can often be planted by volunteers such as Boy Scouts and Girl Scouts. Use of volunteers enhances the benefits by adding educational and publicity aspects to the program. When stabilization measures are proposed in a legal drain, both the county surveyor and the county drainage board should be contacted.

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5.5.2 Roadway Erosion Control

The roads in the watershed cross many streams and drainage ways that are tributary to the Indian Lakes. Stormwater runoff from the roads and from the lands adjacent to the roads travel down the road shoulders and discharge sediments and nutrients into the waterways and eventually into the lakes.

The road shoulders are maintained by the transportation department usually to cut down extraneous weeds and grass. This often results in increased stormwater runoff with increased water velocity, increased erosion, and increased pollutant loading to the waterbodies.

Loon Lake

All areas where stormwater from roadways are contributing excessive sediments into nearby streams and drainage ways should be identified. The degree of soil loss for the identified areas should be classified as slight, moderate, or severe. For those areas contributing large amounts of sediment to nearby watercourses or drainage ways, vegetative or structural controls should be implemented.

Goose Lake

All areas where stormwater from roadways are contributing excessive sediments into nearby streams and drainage ways should be identified. The degree of soil loss for the identified areas should be classified as slight, moderate, or severe. For those areas contributing large amounts of sediment to nearby watercourses or drainage ways, vegetative or structural controls should be implemented.

5.6 Homeowner Best Management Practices

Within the Loon and Goose Lakes watershed, homeowners may contribute a significant amount of sediments and nutrients loadings to nearby watercourses, which may eventually affect the water quality of downstream lakes. The following section discusses homeowner best management practices that are strongly recommended for all property owners in the Loon and Goose Lakes watershed.

5.6.1 Routine Septic Maintenance

Routine maintenance of septic systems is necessary to insure that shallow groundwater is not contaminated with chemicals and nutrients. By properly maintaining septic systems, the nutrient loadings to nearby watercourses are greatly reduced. The county health departments may aid the lake associations by performing on-site inspection of older septic systems. Failing systems should be repaired. Where clusters of failing systems are identified, the installation of small community treatment systems may be required.

5.6.2 Pesticide and Fertilizer Management

The use of pesticides and lawn fertilizers should be kept to a minimum. These chemicals should only be applied during the times when runoff is at a minimum. Within the Loon and Goose Lakes watershed, homeowners who elect to use lawn fertilizers should be encouraged to have their soils tested every 3 years. Homeowners should contact a local soil testing firm for more information regarding soil sample collection and soil analyses. Soil testing for homeowner lawns typically range from $6 to $10. Based on soil analyses, soil testing services generally provide both liming and fertilizing recommendations. By having their soils tested every few years, homeowners reduce the risk of over-fertilizing their lawns, which in turn reduces the amount of nutrients that may be washed into nearby lakes and streams.

5.6.3 Erosion Control

Each homeowner is encouraged to reseeded all exposed soils. By ensuring complete vegetative cover for all soils, sediment and nutrient loadings to nearby watercourses will be reduced.

5.6.4 Establishment of Buffer Strips

Homeowners with lawns that are immediately adjacent to streams and lakes should consider establishing buffer strips. Buffer strips may consist of ornamental tree and shrub plantings. By allowing a small path through the buffer strip, the homeowner still retains access to the watercourse while reducing both sediment and nutrients loadings to lakes and streams.

5.7 Results of AGNPS Modeling & GIS

The Agricultural Non-Point Source (AGNPS) (Young, at al., 1990) model was used to evaluate watershed conditions during a 1 year/24 hour storm. The model was used to highlight areas that have a high potential for contributing to the pollutant load of each lake. The model is developed by dividing the direct watersheds into equally sized cells and determining over twenty input factors for each cells. Some of the factors examined where high slopes, high soil erodibility, and high sediment erosion. Model input parameters were obtained from county soil maps, cropping estimates by the County SCS office, and from 1989 aerial photographs provided by the Whitley County ASCS office. The direct watersheds of the lakes were divided into 40 acre cells. These cells were subdivided into ten acre cells near the lakes to increase the accuracy.

While AGNPS results can not pinpoint exact spots where high erosion is occurring, it provides an overall indication of those areas in the watershed where Best Management Practices should be considered. The model output identifies those areas where field personnel of the SCS and other agencies should concentrate their efforts in order to control erosion and non-point source pollution. The model was not designed to target site-specific problems or model the effects of site-specific Best Management Practices.

Land use information was obtained for the models by projecting 1989 aerial photographs of the watersheds on a USGS base map and color-coding the following land use types: forest, wetlands, row crops, pastures, and residential. Gridded overlays were used to determine the predominant land use for each cell. Crop rotation, common tillage methods, fertilization levels and conservation cropping (C) factors were obtained by personal communication with Joe Updike, SCS. Gridded overlays were used to transfer these factors to individual AGNPS cells. Existing BMP's (WASCOB, animal waste facilities, grassed waterways), areas of high gulley erosion, and the location of feedlots and livestock operations were also marked on this map and transferred to the appropriate AGNPS cells using the gridded overlays.

Soil survey maps were digitized and entered into a geographic information system. Information on soil characteristics, such as k factors, slope length, percent slope, LS factors, and RKLS factors were obtained from County specific soil tables provided by the SCS. This information was entered into the GIS. Weighted averages were then calculated from the GIS database for the various parameters. The predominate soil types for each cell were determined using a gridded overlay in the GIS that corresponded to the AGNPS cells. Runoff curve numbers for each cell were obtained from standard runoff curve numbers tables based upon the predominant land use and soil group. A practice factor of 1.0 was used to simulate worse-case conditions, as recommended by the model's creators. Rainfall intensities came from SCS guidelines for Indiana. The balance of the model inputs were based upon model recommendations and from information in the Agricultural Handbook No. 537 (Wischmeier and Smith, 1978).

The AGNPS model provides limited capabilities to examine the effects of best management practices on controlling watershed erosion. The AGNPS models for the lakes was run with a practice factor of 0.38, which simulates contour stripcropping and similar practices. We also examined the reductions in sediment erosion in each cell (cell erosion, tons/acre), sediment generated in each cell (tons), and the sediment that left each cell and passed downstream to the next cell (cell yield, tons).

A figure was generated using the GIS to illustrate the suitability of soils in the Loon and Goose watersheds. This figure, included in Appendix E, shows that the majority of the soils in the watersheds have severe limitations for use with septic systems.

5.7.1 Loon Lake

As shown in Appendix E, there is a large proportion of the watershed with erodible soils ($k > 0.25$). Not surprisingly, there is also a relatively large proportion of the watershed where erosion is contributing from ½ to 1 ton of sediment per acre, and some areas which are contributing greater than 1 ton per acre. There are also some areas where the slopes are greater than 8 percent. Best Management Practices should be targeted for all of these areas, but particularly where two or more of these parameters overlap.

Based upon the model run using a practice factor of 0.38, Loon Lake received a reduction in sediment load and suspended sediment concentration of approximately 40.0 percent. The average percent reduction in cell erosion was 62.8 percent and ranged from 55.6 to 100.0 percent. The average percent reduction in sediment generated within each cell was 62.1 percent and ranged from 50.0 percent to 100.0 percent. The average percent reduction in cell yield was 55.8 percent and ranged from 0.0 percent to 61.7 percent. The results of this modeling indicates that aggressive watershed management could have a significant impact on the water quality of Loon Lake.

5.7.2 Goose Lake

As shown in Appendix E, there is a large proportion of the watershed with erodible soils ($k > 0.25$). Not surprisingly, there is also a relatively large proportion of the watershed where erosion is contributing from ½ to 1 ton of sediment per acre, and some areas which are contributing greater than 1 ton per acre. There are also some areas where the slopes are greater than 8 percent. Best Management Practices should be targeted for all of these areas, but particularly where two or more of these parameters overlap.

Based upon the model run using a practice factor of 0.38, Goose Lake received a reduction in sediment load and suspended sediment concentration of approximately 44.8 percent. The average percent reduction in cell erosion was 61.8 percent and ranged from 58.8 to 63.3 percent. The average percent reduction in sediment generated within each cell was 62.2 percent and ranged from 61.9 percent to 66.7 percent. The average percent reduction in cell yield was 58.1 percent and ranged from 0.0 percent to 61.7 percent. The results of this modeling indicates that aggressive watershed management could have a significant impact on the water quality of Goose Lake.

6.0 Recommended Management Plan for Loon and Goose Lakes

Based on the data collected during the diagnostic portion of this study and the research into the feasibility of various lake and watershed management techniques presented in Sections 4 and 5 of this report, a recommended program to address the water quality problems in Loon and Goose Lakes has been developed. Since most of the pollutant loads originate from nonpoint sources in the drainage basin, significant improvement in lake water quality will come about slowly as land management practices are implemented throughout the watershed. After the lakes have had sufficient time to respond to watershed management practices, nutrient inactivation should be reevaluated for both Loon and Goose Lakes if water quality does not improve. In the meantime, in-lake treatment for controlling nuisance aquatic plants is recommended to the extent necessary to enhance recreational use while maintaining or enhancing ecological aspects of each lake.

Population growth in the area stresses services, such as schools (LaGrange News, April 19, 1991), roads, and the environment. Now is the time to plan for growth by deciding which areas are in greatest need of protection, and how that protection is to be accomplished. Wetlands and undisturbed forested areas are important for wildlife habitat, groundwater recharge, and improvement of surface water quality. The lakes are crucial to the economic, aesthetic, and recreational well-being of the entire area.

Many of the recommended alternatives will necessitate a close working relationship among the important user groups, local residents, local government, and the advisory and regulatory agencies. Key organizations include all the lake associations, the County Health Department, the Whitley and Noble County Soil and Water Conservation Districts, the Soil Conservation Service, and the Agricultural Stabilization and Conservation Service.

6.1 Institutional

The Loon Lake Property Owners Association and The Goose Lake Association should combine their efforts by establishing a watershed management district, which would serve the entire Loon and Goose Lakes watershed region. The watershed management district may be set-up as a non-profit organization or as a conservancy district. One advantage in establishing the watershed management district as a conservancy district is that the watershed management district would have taxing powers. In the Pocono Region of Pennsylvania, a good example of a non-profit watershed management district is the Lake Wallenpaupack Watershed Management District (LWWMD). For over ten years, LWWMD has been highly successful in protecting the water quality in Lake Wallenpaupack. LWWMD was established in the late 1970's with the assistance of F. X. Browne Associates, Inc. In any event, the watershed management would be responsible for overseeing all activities that may impact the water quality of Loon and Goose Lakes.

The advisory committee (or board of directors) of the watershed management district should include all appropriate government representatives, other people who can offer valuable technical and planning expertise, and at least one representative from the Loon and Goose Lake Associations. The functions of the watershed management district would be as follows: 1) coordination of effort among Whitley and Noble Counties to accomplish watershed and lake management activities, 2) provision of technical and advisory assistance to local governments, homeowners, businesses, developers, and farmers, 3) development of model programs and ordinances, including erosion and sedimentation ordinances for new construction and a stormwater runoff ordinance to control water quality and flooding, 4) prioritization of watershed and lake management activities, which encompass the implementation of best management practices within the watershed, and further lake and watershed studies, and 5) financial management of lake and watershed programs, which includes the acquisition of state, federal and private funds to be used for various projects throughout the watershed.

The watershed management district for Loon and Goose Lakes would have no taxation or enforcement powers, hence these activities would be accomplished through the existing power base. Enforcement and taxation bodies would look to the watershed management district for guidance on watershed-related activities. A formal organization plan for the watershed management district should be drawn up immediately so that action can begin on management activities for Loon and Goose Lakes.

Another important function of the watershed management district would be to develop educational materials and conduct educational programs for regulatory people, school children, and the public at large. One important activity which should be part of the educational program is a "Watershed Watch" program. An educational fact sheet could be distributed which describes potential pollutant sources (eroding land, gasoline, oil, or chemical spills, etc.), and gives a telephone number to contact if someone sees a possible problem.

The watershed management district would also be involved in land use planning activities which would protect or improve the water quality in Loon and Goose Lakes. Such activities might include land acquisition, conservation easements, and land trusts.

6.2 Watershed Management Plan

For the water quality in Loon and Goose Lakes to significantly improve, the lands throughout the entire watershed must be managed in an environmental sound manner to reduce nutrient and suspended solid loadings to these lakes. Watershed management guidelines include the following: the implementation of agricultural best management practices (Ag BMP's), homeowner best management practices, waste-water management practices, and stabilization practices for both streambanks and roadways. In addition, erosion control and stormwater runoff ordinances should be established within the boundaries of the lakes watershed.

6.2.1 Agricultural Best Management Practices

Within the Loon and Goose Lakes watershed, the watershed management district should work closely with the Whitley and Noble County Soil and Water Conservation Districts (SWCD), the Soil Conservation Service (SCS), and the Agricultural Stabilization and Conservation Service (ASCS) to identify all areas requiring the implementation of agricultural best management practices (Ag BMP's). In identifying these areas, the output from AGNPS modeling (included as part of this report) and field investigations should be used. Once identified, these areas should be ranked on the following criterion: benefit to water quality, cost of implementation, and participation interest of land owner. For many of the Ag BMP's, the amount of funding available will determine the number of projects completed. On the other hand, some low-cost Ag BMP's could be addressed immediately, such as restricting livestock from entering watercourses, controlling fertilizer application dosages, applying fertilizer to land during times when runoff is minimize, and creating buffer areas between agricultural fields and water bodies.

Below is a list of agricultural best management practices and their applicability in the Loon and Goose Lakes entire watershed:

Conservation tillage (no-till) in combination with integrated pest management is strongly suggested within the Loon and Goose Lakes region. By implemented these best management practices, off-site transport of nutrients, sediment and pesticides can be minimized.

Cover cropping is strongly recommended in the Loon and Goose Lakes region. By providing cover for agricultural lands throughout the year, soil losses will be minimized.

Critical area planting is recommended for areas subject to high erosion. In these areas, permanent vegetation should be established, thereby reducing nutrient and sediment loadings to nearby watercourses.

Terraces on lands will be of limited value in the Loon and Goose Lakes watershed since regional topography is relatively flat. In site specific areas, where long, steep slopes occur, terracing may be useful in controlling soil erosion.

Grassed waterways are recommended throughout the Loon and Goose Lakes watershed. Drainage swales exhibiting excessive soil erosion should be regraded and seeded with grasses that are tolerant of wet soil conditions.

Farmland management practices are strongly recommended in the Loon and Goose Lakes watershed. Farmland management includes both pasture and hayland management, plus the establishment buffer strips between livestock and watercourses. By implementing these farmland management practices, both nutrient and sediment loadings to the lakes will be greatly reduced.

Agricultural waste storage facilities are strongly suggest in the Loon and Goose Lakes watershed. By storing animal wastes until soil conditions are conducive for land applications, nutrient loadings to nearby watercourses will be significantly reduced.

Buffer strips along nearly every foot of stream/ditch is recommended. By allowing buffer strips between agricultural lands and adjacent streams and lakes, these watercourses will be protected from excessive sediment and nutrient loadings.

Impoundment ponds to collect sediment and nutrients where terraces are recommended. By trapping sediments carried by runoff, downstream water courses will be protected.

6.2.2 Homeowner Best Management Practices

Within the Loon and Goose Lakes watershed, homeowners can make a significant contribution in reducing the amounts of sediments and nutrients loadings to nearby watercourses, which may eventually affect the water quality of downstream lakes. The watershed management district with the cooperation of the Whitley and Noble County Soil and Water Conservation Districts (SWCD), the Soil Conservation Service (SCS), the Agricultural Stabilization and Conservation Service (ASCS), and the Whitley and Noble County Health Departments, should educate the public with regard to homeowner best management practices through public seminars and by mail. The following homeowner best management practices, are strongly recommended.

Routine maintenance of septic systems is critical in maintaining high water quality. By properly maintaining septic systems, the nutrient loadings to groundwater and downstream watercourses are greatly reduced. Failing septic systems may be identified by septic leachate studies and/or on-site inspections by the watershed management district with the cooperation of the county health departments. Failing systems should be repaired and where clusters of failing systems are identified, the installation of small community treatment systems may be required.

The use of pesticides and lawn fertilizers should be kept to a minimum and applied during the times when runoff is minimized. Homeowners should have their soils routinely tested. Along with test results, recommended amounts and type of fertilizers are typically offered. By applying fertilizers in the appropriate amount and under satisfactory soil conditions, nearby surface waters are further protected.

All exposed soils should be reseeded, thereby reducing sediment loadings to nearby watercourses.

In areas where lawns and watercourses are contiguous, homeowners should establish buffer strips. Buffer strips may consist of ornamental tree and shrub plantings that separate the lake or stream bank from lawned areas. By allowing a small path through the buffer strip, the homeowner still retains access to the watercourse and reduces both sediment and nutrients loadings to lakes and streams.

6.2.3 Wastewater Management Practices

In many instances, septic systems may directly deliver nutrients to the shallow waters of the lake, thereby contributing to excessive macrophytic growth and algal blooms. The only way to eliminate loading from septic systems is to install a community wastewater collection and treatment system.

Within the Loon and Goose Lakes watershed, the watershed management district should encourage a wastewater treatment plant feasibility study for Loon and Goose Lakes. This study should focus on septic systems in the vicinity of the two lakes. It has been estimated that Goose Lake receives approximately 21 percent of its phosphorus loading from nearby septic systems, while Loon Lake receives 12 percent of it phosphorus from septic systems.

6.2.4 Erosion and Runoff Control

Erosion and sedimentation ordinances and stormwater runoff ordinances should be developed for the watershed by the watershed management district, for adoption by the Whitley and Noble County governments. There are technical manuals published by the SCS which are designed to give guidance to localities in these areas.

Erosion Control Ordinance

A model erosion and sediment control ordinance to control erosion from construction sites should be developed. The ordinance should include technical guidelines and typical details for the installation of erosion and sediment control measures. These guidelines should discuss and recommend methods for controlling soil erosion and sedimentation, including the use of silt fences, straw bales, diversions, channel lining and other erosion control measures. Details and design specifications for the installation of silt fence, straw bales, construction entrances and other standard methods should be included. Procedures for review of erosion control plans and inspections of construction sites should also be included. Some useful information regarding soil erosion control is provided in a publication entitled A Model Ordinance for Erosion Control on Sites with Land Disturbing Activities, which is put out by the Highway Extension and Research Project, and Indiana Cities and Counties (HERPICC). This publication may be obtained through the Civil Engineering Department at Purdue University in West Lafayette, Indiana.

Stormwater Runoff Control Ordinance

A model runoff control ordinance should be developed which can be adopted and implemented by Whitley and Noble Counties. Unlike the proposed erosion and sediment control ordinance which is designed to control erosion and runoff during construction activity, the runoff control ordinance is designed to control erosion and runoff after construction activities are complete, for the life of the project.

The runoff control ordinance should be developed on the basis of the environmental performance standards that the peak stormwater runoff and the pollutant loads from a new development or facility shall not exceed the pre-development levels.

The runoff control ordinance should include methods for calculating runoff flows and velocities, design storm requirements, rate of runoff control requirements and water quality standards. If detention or retention facilities are required, the ordinance should include design standards for these facilities for freeboard, emergency spillways, bottom slope and other technical or safety requirements. The ordinance should also include procedures for an engineering review of the plan and inspections during construction.

Streambank Stabilization

The watershed management district should identify areas of streambank erosion and classify the erosion of those areas as slight, moderate, or severe. Streambank erosion can be corrected by 1) reducing the amount and velocity of water in the stream, 2) installing relatively high cost structural controls such as rip-rap and gabions, and 3) installing relatively low-cost vegetative controls such as willow twigs, shrubs or grasses. Low-cost vegetative controls should be used wherever practical to control moderate and severe streambank erosion. Trees, grasses, and shrubs which can withstand both desiccation and submersion are recommended. The Whitley and Noble County Soil and Water Conservation Districts' can provide technical assistance. Vegetative controls can often be planted by volunteers such as Boy Scouts and Girl Scouts. Use of volunteers enhances the benefits by adding educational and publicity aspects to the program. When streambank stabilization is proposed in legal drains, both the county surveyor and the county drainage board should be consulted.

Roadway Erosion Control

The watershed management district should identify roadway and stream crossing problem areas and classify the problem areas as slight, moderate, or severe. Both structural and vegetative controls should be used to reduce the sediment and nutrient entering the waterways.

6.2.5 Constructed Wetlands

A wetland basin with a surface area of at least 12 acres and an average depth of 3.5 feet should be constructed on Friskney Ditch close to where it enters Loon Lake. Under optimum conditions (shape and water path), a basin of this size would remove an estimated 90 percent of the sediment and 60 percent of the phosphorus load carried by the stream (Driscoll, 1983). Based upon the drainage area of Friskney Ditch and the estimated pollutant budget for Loon Lake, the wetland basin would reduce the annual total suspended sediment loading to the lake by 27 percent, removing approximately 362,170 kilograms (798,450 pounds) of sediment per year. The wetland basin would reduce the total phosphorus loading to the lake by 18 percent, removing approximately 660 kilograms (1,455 pounds) of phosphorus per year.

6.3 In-Lake Management Plan

For Loon and Goose Lakes, the success of in-lake management strategies is highly dependent on the success of watershed best management practices. Watershed best management practices (Ag BMP's, homeowner best management practices, wastewater management practices, and stormwater and roadway erosion control practices) can significantly reduce the amount of incoming nutrients and sediments to a lake from the surrounding watershed. By reducing the quantity of incoming nutrients and sediments to a lake, the water quality of a lake is expected to gradually improve. Therefore, watershed management practices should be implemented prior to or in conjunction with any recommended in-lake management strategies.

In contrast to the watershed management plans, in-lake management plans are tailored to individual lakes. In-lake management plans must take into account the physical, chemical and biological characteristics of the lake in question and its surrounding watershed; therefore, what is recommended for one lake may be inappropriate for another lake. In addition to the applicability of the in-lake restoration alternative, an in-lake restoration alternative must also be cost-effective, impose few if any negative impacts to the environment, and should benefit a substantial number of lake users. Based on the above criterion, recommended in-lake management alternatives for Loon and Goose Lakes are discussed below.

7.0 Environmental Evaluation

Since socio-economic and environmental impacts are part of the cost-effectiveness analysis for the restoration of Loon and Goose Lakes, many of these impacts were addressed during the evaluation of restoration alternatives. However, the impacts and their mitigative measures are formally documented below using the environmental evaluation checklist in the Clean Lakes Program Guidance Manual (U.S. EPA, 1980).

1. Will the project displace people?

   No.

2. Will the project deface existing residences or residential areas?

   No. Residential areas are not affected by the proposed plan.

3. Will the project be likely to lead to changes in established land use pattern or an increase in development pressure?

   Possibly. If a sewer system is expanded or installed, developmental pressures could increase. Improving agricultural lands through the installation of BMP's may actually enhance the desirability of the land for continued agricultural usage.

4. Will the project adversely affect prime agricultural land or activities?

   No. The recommended Best Management Practices (BMP's) will reduce sediment and nutrient losses from cropland and pastureland and should benefit agricultural activities.

5. Will the project adversely affect parkland, public land or scenic land?

   No. Restoration activities will greatly enhance the recreational and aesthetic uses of the lake and adjacent park, public and scenic land.

6. Will the project adversely affect lands or structures of historic, architectural, archeological or cultural value?

   The project as planned involves no modifications to or activities which will impact existing structures. No lands which have not already been altered by agricultural or other development activities will be affected.

7. Will the project lead to a significant long-range increase in energy demands?

   The selected restoration alternatives will not cause any significant increases in energy demand over the long-term.

8. Will the project adversely affect short-term or long-term ambient air quality?

   Air quality may be affected over the short-term due to construction activities associated with agricultural BMP installation. All construction equipment should have proper emission controls and proper dust control practices should be used. Modern aquatic weed harvesters should not adversely affect air quality if properly maintained and operated.

9. Will the project adversely affect short-term or long-term noise levels?

   Noise levels may be temporarily affected by harvesting and construction activities. All construction vehicles and equipment should use noise control devices.

10. If the project involves the use of in-lake chemical treatment, will it cause any short-term or long-term effects?

    No in-lake chemical treatments are recommended.

11. Will the project be located in a floodplain?

    Some of the proposed agricultural BMP's and stream bank stabilization activities would be located in floodplains, although no adverse effects are expected.

12. Will structures be constructed in the floodplain?

    The use of check dams and detention/retention basins are recommended. Check dams are to be installed within a stream's corridor, therefore check dams will evidently fall within the boundaries of a floodplain. Retention/detention basins may or may not be sited within the boundaries of a floodplain. The actual location of a proposed basin will be highly dependent on local site conditions. The outfall structure of a basin will discharge runoff directly into an adjacent watercourse; hence these structures will also need to be constructed within a floodplain.

Prior to any construction activities associated with the above structures, all the necessary state and/or federal permits will be submitted. The construction of a check dam or a detention/retention basin will only commence after receiving final approval in writing by the appropriate state and federal agencies.

13. If the project involves physically modifying the lake shore, its bed, or its watershed, will the project cause any short or long-term adverse effects?

    Construction activities, such as those involved in constructing sedimentation basins or check dams, could result in the transportation of nutrients, sediments or other pollutants to downstream waters. All earthmoving activities will be conducted in a way to minimize the erosion potential and minimize in-lake turbidity.

14. Will the project have a significant adverse effect on fish and wildlife, wetlands or other wildlife habitat?

    No adverse effects are expected. The planting of buffer strips, streambank stabilization, and revegetation of exposed eroding areas will have secondary benefits and will expand habitat areas for birds and mammals. As for the installation of benthic barriers, the loss of habitat for fish and benthic organisms is inevitable, but the proposed areas that will be affected are only a minute fraction of total available habitat in Loon and Goose Lakes.

15. Have all feasible alternative to the project been considered in terms of environmental impacts, resource commitment, public interest and cost?

    All feasible alternatives for restoring Loon and Goose Lakes have been thoroughly analyzed. The recommended plan has minimal negative environmental impacts, and implementation of BMP's will improve management of land resources and water quality. Because of the complexity of the problems encountered in these lakes and their watershed, the recommended approach using both in-lake and watershed management practices appears to be the most cost-effective method to improve fishing, boating, aesthetics, and other lakeside uses.

16. Are there other measures not previously discussed which are necessary to mitigate adverse impacts resulting from the project?

    There are no possible mitigation measures known at the present time which have not been discussed.

8.0 Public Participation

A public meeting was held in August 1991. The results of the lake monitoring program were presented along with the analysis of restorative and management alternatives. The objective of this meeting was to inform the public on the water quality status of Loon and Goose Lakes, present the conclusions and recommendations of this report, answer any questions regarding the Loon and Goose Lakes study, and receive the public's input regarding proposed lake and watershed restoration alternatives.

9.0 Implementation Program

In order to implement the recommended management plan for Loon and Goose Lakes, a plan of action is needed, setting forth a schedule of target dates for specific activities, and potential funding sources. The following sections describe potential federal and state funding programs, water quality monitoring and documentation necessary for assessment of the effect of restoration methods on water quality, and a summary and schedule of the management plan for Loon and Goose Lakes.

9.1 Financial Assistance

Recent trends in state and federal funding indicate that implementation of the recommended management plans for Loon and Goose Lakes may have to derive funds from a variety of sources. The following is a description of additional state and federal funding that may be available for Loon and Goose Lakes.

Once a lake feasibility study has been conducted under The Indiana Department of Natural Resources' Lake Enhancement Program, additional state funding for the implementation of both lake and watershed management plans may be available through the Department. The actual implementation of lake and watershed management plans may be funded through the Department's Lake Enhancement Program and the Lake and Watershed Land Treatment Program, respectively.

Under the Federal Water Pollution Control Act (Clean Water Act) as amended by Water Quality Act of 1987 (P.L. 100-4), the U.S. Environmental Protection Agency (EPA) administers funding for lake diagnostic-feasibility studies and the implementation of lake restoration and watershed best management practices. Under Section 314, the Clean Lakes Program, federal funding is available for Phase I lake studies and Phase II projects. Phase I studies are focused on diagnosing lake problems and developing feasible lake restoration alternatives. Phase II projects are aimed at lake restoration by implementing those recommendation offered as part of the Phase I studies. Under Section 319, Nonpoint Source Management Programs, federal funding is available for the implementation of agricultural best management practices to reduce agricultural nonpoint sources of pollution.

The Loon and Goose Lakes study, which was funded under Indiana's Lake Enhancement Program, does not meet the requirements of an EPA Phase I study. Therefore, the Loon and Goose Lakes do not qualify for EPA funding for Phase II projects under Section 314, but these lakes may qualify for Phase I funding under Section 314 and additional funding under Section 319.

In addition to the state's Lake and Watershed Land Treatment Program, and the EPA's Nonpoint Source Management Programs, several other programs are available to help defray the costs of implementing agricultural best management practices. The Agricultural Conservation Program under the U.S. Department of Agriculture, Soil Conservation Service, is a cost-sharing program, which funds 75 percent of costs for a particular agricultural best management practice up to $3,500 per year per farm. Similarly to the Soil Conservation Service, several other cost-sharing programs are available to individual land owners through the Agricultural Stabilization and Conservation Service (ASCS).

9.2 Future Monitoring

With or without state or federal funding, a baseline monitoring program for Loon and Goose Lakes should continue, thereby documenting the water quality status of these lakes. For any lake system, the early detection of water quality deterioration is extremely important and the documentation of the lake's physical, biological and chemical status may prove to be an invaluable source of information with regard to future work for Loon and Goose Lakes or within the boundaries of the Loon and Goose Lakes watershed.

The watershed management district should encourage individuals within the watershed to get involved with the Volunteer Lake Monitoring Program offered by the Indiana Department of Environmental Management (IDEM).

9.3 Management Plan Schedule and Summary

The management plan for Loon and Goose Lakes is subdivided into a watershed management plan and individual lake management plans. In the paragraphs to follow, a watershed management plan and lake management plan for each lake is presented below.

9.3.1 Watershed Management Plan

Due to the fact that Loon and Goose Lakes are hydrologically interconnected, the water quality of Loon Lake is indirectly influenced by all upstream watershed activities. Therefore, it is of the utmost importance that a watershed management plan, serving the entire Loon and Goose Lakes watershed, be established. The Loon and Goose Lakes watershed management plan primary goal is to reduce nutrient and sediment losses from lands located throughout the entire watershed. The watershed management plan for the entire Loon and Goose Lakes' region is summarized in Table 9.1.

Table 9.1 Loon and Goose Lakes Watershed Management Plan	
Activity	**Target Date**
Formation of the Loon and Goose Lakes Watershed Management District	Spring 1992.
Identify sources of funding and apply for funding	Immediately after Watershed Management District is formed, ongoing.
Develop erosion control ordinance	Summer 1992.
Develop stormwater runoff ordinance	Summer 1992.
Identify areas requiring the implementation of agricultural best management practices	Summer 1992. Ongoing
Wastewater feasibility studies	Summer 1992
Design study of impoundment pond in Friskney Ditch	Fall 1992.
Public education	Fall 1992. Ongoing.
Implement agricultural best management practices	Fall 1992. Ongoing.
Inspect septic system and investigate alternatives	1992
Identify areas in need of streambank stabilization, implement stabilization	1992. Ongoing.
Identify areas in need of roadway stabilization, implement stabilization	1992. Ongoing.

9.3.2 Lake Management Plans

For Loon and Goose Lakes, lake management plans are summarized in Tables 9.2 and 9.3. All lake management plans should be coordinated through the newly appointed watershed management district. The district would also be responsible for seeking out funds for both watershed and lake management plans. For both Loon and Goose Lakes, lake management plans are primarily focused on controlling aquatic vegetation that are currently treated by herbicides. Other in-lake restoration alternatives, such as nutrient inactivation for Goose Lake, should be reevaluated at a later date when both nutrient and sediment loadings are significantly reduced.

Loon Lake

As shown in Table 9.2, the management plan for Loon Lake includes the installation of benthic barriers in the vicinity of docks, localized weed harvesting in those areas that are currently treated with herbicides. For benthic barriers, the estimated cost to cover an area of 400 square feet is $40 for polypropylene materials and $120 for fiberglass netting, and does not include installation fees or special materials, such as benthic anchors. Localized weed harvesting is approximately $225 to $375 per acre and does not include hauling fees to the disposal site.

Table 9.2
Lake Management Plan for Loon Lake

Activity	Target Date
Installation of Benthic Barriers	Spring 1992.
Localized Weed Harvesting (if deemed necessary by the lake association)	Spring 1992.
Nutrient Inactivation	Revaluate after nutrient and sediment loadings are reduced.

Goose Lake

As shown in Table 9.3, the management plan for Goose Lake includes the installation of benthic barriers in the vicinity of docks, localized weed harvesting in those areas that are currently treated with herbicides. For benthic barriers, the estimated cost to cover an area of 400 square feet is $40 for polypropylene materials and $120 for fiberglass netting, and does not include installation fees or special materials, such as benthic anchors. Localized weed harvesting is approximately $225 to $375 per acre and does not include hauling fees to the disposal site.

For Goose Lake, nutrient inactivation (i.e. alum treatment) may be cost-effective after the both nutrient and sediment loadings from nonpoint sources are reduced. After nutrient and sediment loadings have been significantly reduced, nutrient inactivation should be reevaluated at this time.

Table 9.3
Lake Management Plan for Goose Lake

Activity	Target Date
Installation of Benthic Barriers	Spring 1992.
Weed Harvesting (Lake and Channels)	Spring 1992.
Nutrient Inactivation	Revaluate after nutrient and sediment loadings are reduced.

9.4 Permit Requirements

Based on conversations with representatives of the Indiana Department of Natural Resources (IDNR) the Indiana Department of Environmental Management (IDEM) and the United States Department of the Army, Corps of Engineers the following is a list of permit requirements for the recommended watershed and in-lake restoration methods.

9.4.1 In-lake Methods

Weed Harvesting	no permit requirements as long as root structures are not disturbed.
Herbicides	Weed Control Permit must be submitted to IDNR ($5). Available for control of submersed macrophytes plus duckweed and purple loosestrife.
Benthic Barriers	Proposal must be submitted to IDNR. 404 Permit may be required by the Corps of Engineers ($10 - $100).
Nutrient Inactivation	Proposal must be submitted to IDNR and IDEM. 404 Permit may be required by the Corps of Engineers ($10 - $100).

Sediment Dredging	Lake Preservation Act Permit may be required.
	Construction in a Floodway Permit may be required.
	Ditch Act Permit may be required.
	404 Permit must be submitted to Corps of Engineers ($10 - $100).
Hypolimnetic Aeration	Proposal must be submitted to IDNR.

9.4.2 Watershed Methods

Check Dams	Construction in a Floodway Permit must be submitted to IDNR ($50).
	404 Permit maybe required by the Corps of Engineers ($10 - $100).
Retention\ Detention Basins	Construction in a Floodway Permit must be submitted to IDNR ($50).
	404 Permit maybe required by the Corps of Engineers ($10 - $100).

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Appendix A

Lake Ecology Primer

Lake Ecology Primer

The ecological conditions of any lake is the summation of physical, chemical, and biological processes which occur in it. Temperature and dissolved oxygen measurements are usually reliable means of evaluating the ecological conditions of a lake. Life processes in the upper well lighted waters result in the uptake of nutrients and in the production of oxygen and organic material. At the bottom, the absence of light results in an environment which is colder than the surface and often devoid of dissolved oxygen. Photosynthetic production by green plants is the predominant life process at the surface while bacterial decomposition is the predominant process at the bottom. The supply of dissolved oxygen at the bottom may be depleted by bacterial decomposition and by various chemical processes associated with nutrient cycling.

Dissolved oxygen is necessary to support most forms of aquatic life. A minimum dissolved oxygen concentration of 5.0 milligrams per liter is usually required to support most fish. Warm water fish, such as bass and perch, often survive at lower oxygen levels. Oxygen levels in lakes are directly related to physical, chemical and biological activities occurring in the lake water. Measurement of dissolved oxygen is therefore an excellent indicator of the overall water quality of a lake.

Although lakes are usually in a balanced condition, two types of natural long-term changes are occurring: (1) The lake is gradually filling in with soil from upstream and surrounding land areas; and (2) the additional materials carried to the lake area usually stimulate increased plant production. The lake fills with both sediment and with the remains of plants and animals. The number of dead plants and animals increases as the production of organisms increases. These processes usually cause lakes to become shallower. The lake gradually tends to fill completely. As this process, called succession or aging, continues, the types of animals and plants also begin to change. Game fish such as bass, pike, and pan fish may be replaces by rough species such as carp, suckers, and bullheads. Rough fish are better adapted to live in a lake which is relatively old on the time scale of succession. Eventually the lake or pond becomes a bog or swamp. In turn the swamp tends to continue to fill in and, if conditions are right, a forest takes over.

Depending on the natural environmental conditions, the process of natural succession may take hundreds or even thousands of years. The actions of man, however, can considerably accelerate this aging process. It can be said, therefore, that lakes have both a chronological and ecological age. The chronological age is simply the number of years a lake has existed. The ecological age, on the other had, is a measure of the physical, chemical, and biological conditions of a lake. Relative to ecological age, most lakes are classified as being either oligotrophic, mesotrophic or eutrophic. An oligotrophic lake is an ecologically "young" lake that usually has low nutrient levels and low plant and animal productivity. A mesotrophic lake can be considered to be a "middle-aged" lake that contains average amounts of nutrients and has an average plant and animal productivity. A eutrophic lake is one that has a high nutrient content and a high plant and animal productivity. During the spring, summer, and fall, a eutrophic lake usually has an algal bloom or an excessive growth of aquatic plants.

Appendix B

Glossary of Lake and Watershed Terms

GLOSSARY OF LAKE AND WATERSHED MANAGEMENT TERMS

Aeration: A process in which water is treated with air or other gases, usually oxygen. In lake restoration, aeration is used to prevent anaerobic condition or to provide artificial destratification.

Algal bloom: A high concentration of a specific algal species in a water body, usually caused by nutrient enrichment.

Algicide: A chemical highly toxic to algae.

Alkalinity: A quantitative measure of water's capacity to neutralize acids. Alkalinity results from the presence of bicarbonates, carbonates, hydroxides, salts, and occasionally of borates, silicates, and phosphates. Numerically, it is expressed as the concentration of calcium carbonate that has an equivalent capacity to neutralize strong acids.

Allochthonous: Describes organic matter produced outside of a specific stream or lake system.

Alluvial: Pertaining to sediments gradually deposited by moving water.

Artificial destratification: The process of inducing water currents in a lake to produce partial or total vertical circulation.

Artificial recharge: The addition of water to the groundwater reservoir by activities of man, such as irrigation or induced infiltration.

Assimilation: The absorption and conversion of nutritive elements into protoplasm.

Autochthon: Any organic matter indigenous to a specific stream or lake.

Autotrophic: The ability to synthesize organic matter from inorganic substances.

Background loading of concentration: The concentration of a chemical constituent arising from natural sources.

Base flow: Stream discharge due to groundwater flow.

Benthic oxygen demand: Oxygen demand exerted from the bottom of a stream or lake, usually by biochemical oxidation of organic material in the sediments.

Benthos: Organisms living on or in the bottom of a body of water.

Best management practices: Practices, either structural or non-structural, which are used to control nonpoint source pollution.

Bioassay: The use of living organisms to determine the biological effect of some substance, factor, or condition.

Biochemical oxidation: The process by which bacteria and other microorganisms break down organic material and remove organic matter from solution.

Biochemical oxygen demand (BOD), biological oxygen demand: The amount of oxygen used by aerobic organisms to decompose organic material. Provides an indirect measure of the concentration of biologically degradable material present in water or wastewater.

Biological control: A method of controlling pest organisms by introduced or naturally occurring predatory organisms, sterilization, inhibiting hormones, or other nonmechanical or nonchemical means.

Biological magnification, biomagnification: An increase in concentration of a substance along succeeding steps in a food chain.

*From EPA Clean Lakes Manual, 1980.

Biomass: The total mass of living organisms in a particular volume or area.

Biota: All living matter in a particular region.

Blue-green algae: The phylum Cyanophyta, characterized by the presence of blue pigment in addition to green chlorophyll.

Catch basin: A collection chamber usually built at the curb line of a street, designed to admit surface water to a sewer or subdrain and to retain matter that would block the sewer.

Catchment: Surface drainage area.

Chemical control: A method of controlling pest organisms through exposure to specific toxic chemicals.

Chlorophyll: Green pigment in plants and algae necessary for photosynthesis.

Circulation period: The interval of time in which the thermal stratification of a lake is destroyed, resulting in the mixing of the entire water body.

Coagulation: The aggregation of colloidal particles, often induced by chemicals such as lime or alum.

Coliform bacteria: Nonpathogenic organisms considered a good indicator of pathogenic bacterial pollution.

Colorimetry: The technique used to infer the concentration of a dissolved substance in solution by comparison of its color intensity with that of a solution of known concentration.

Combined sewer: A sewer receiving both stormwater runoff and sewage.

Compensation point: The depth of water at which oxygen production by photosynthesis and respiration by plants and animals are at equilibrium due to light intensity.

Cover crop: A close-growing crop grown primarily for the purpose of protecting and improving soil between periods of permanent vegetation.

Crustacea: Aquatic animals with a rigid outer covering, jointed appendages, and gills.

Culture: A growth of microorganisms in an artificial medium.

Denitrification: Reduction of nitrates to nitrites or to elemental nitrogen by bacterial action.

Depression storage: Water retained in surface depressions when precipitation intensity is greater than infiltration capacity.

Design storm: A rainfall pattern of specified amount, intensity, duration, and frequency that is used as a basis for design.

Detention: Managing stormwater runoff or sewer flows through temporary holding and controlled release.

Detritus: Finely divided material of organic or inorganic origin.

Diatoms: Organisms belonging to the group Bacillariophyceae, characterized by the presence of silica in its cell walls.

Dilution: A lake restorative measure aimed at reducing nutrient levels within a water body by the replacement of nutrient-rich waters with nutrient-poor waters.

Discharge: A volume of fluid passing a point per unit time, commonly expressed as cubic meters per second.

Dissolved oxygen (DO): The quantity of oxygen present in water in a dissolved state, usually expressed as milligrams per liter of water, or as a percent of saturation at a specific temperature.

Dissolved solids (DS): The total amount of dissolved material, organic and inorganic, contained in water or wastes.

Diversion: A channel or berm constructed across or at the bottom of a slope for the purpose of intercepting surface runoff.

Drainage basin, watershed, drainage area: A geographical area where surface runoff from streams and other natural watercourses is carried by a single drainage system to a common outlet.

Dry weather flow: The combination of sanitary sewage and industrial and commercial wastes normally found in the sanitary sewers during the dry weather season of the year; or, flow in streams during dry seasons.

Dystrophic lakes: Brown-water lakes with a low lime content and a high humus content, often severely lacking nutrients.

Enrichment: The addition to or accumulation of plant nutrients in water.

Epilimnion: The upper, circulating layer of a thermally stratified lake.

Erosion: The process by which the soils of the earth's crust are worn away and carried from one place to another by weathering, corrosion, solution, and transportation.

Eutrophication: A natural enrichment process of a lake, which may be accelerated by man's activities. Usually manifested by one or more of the following characteristics: (a) excessive biomass accumulations of primary producers; (b) rapid organic and/or inorganic sedimentation and shallowing; or (c) seasonal and/or diurnal dissolved oxygen deficiencies.

Fecal streptococcus: A group of bacteria normally present in large numbers in the intestinal tracts of humans and other warm-blooded animals.

First flush: The first, and generally most polluted, portion of runoff generated by rainfall.

Flocculation: The process by which suspended particles collide and combine into larger particles or floccules and settle out of solution.

Gabion: A rectangular or cylindrical wire mesh cage (a chicken wire basket) filled with rock and used to protect against erosion.

Gaging station: A selected section of a stream channel equipped with a gage, recorder, and/or other facilities for determining stream discharge.

Grassed waterway: A natural or constructed waterway covered with erosion-resistant grasses, used to conduct surface water from an area at a reduced flow rate.

Green algae: Algae characterized by the presence of photosynthetic pigments similar in color to those of the higher green plants.

Heavy metals: Metals of high specific gravity, including cadmium, chromium, cobalt, copper, lead, mercury. They are toxic to many organisms even in low concentrations.

Hydrograph: A continuous graph showing the properties of stream flow with respect to time.

Hydrologic cycle: The movement of water from the oceans to the atmosphere and back to the sea. Many subcycles exist including precipitation, interception, runoff, infiltration, percolation, storage, evaporation, and transpiration.

Hypolimnion: The lower, non-circulating layer of a thermally stratified lake.

Intermittent stream: A stream or portion of a stream that flows only when replenished by frequent precipitation.

Irrigation return flow: Irrigation water which is not consumed in evaporation or plant growth, and which returns to a surface stream or groundwater reservoir.

Leaching: Removal of the more soluble materials from the soil by percolating waters.

Limiting nutrient: The substance that is limiting to biological growth due to its short supply with respect to other substances necessary for the growth of an organism.

Littoral: The region along the shore of a body of water.

Macrophytes: Large vascular, aquatic plants which are either rooted or floating.

Mesotrophic lake: A trophic condition between an oligotrophic and an eutrophic water body.

Metalimnion: The middle layer of a thermally stratified lake in which temperature rapidly decreases with depth.

Most probable number (MPN): A statistical indication of the number of bacteria present in a given volume (usually 100 ml).

Nannoplankton: Those organisms suspended in open water which because of their small size, cannot be collected by nets (usually smaller than approximately 25 microns).

Nitrification: The biochemical oxidation process by which ammonia is changed first to nitrates and then to nitrites by bacterial action.

Nitrogen, available: Includes ammonium, nitrate ions, ammonia, and certain simple amines readily available for plant growth.

Nitrogen cycle: The sequence of biochemical changes in which atmospheric nitrogen is "fixed," then used by a living organism, liberated upon the death and decomposition of the organism, and reduced to its original state.

Nitrogen fixation: The biological process of removing elemental nitrogen from the atmosphere and incorporating it into organic compounds.

Nitrogen, organic: Nitrogen components of biological origin such as amino acids, proteins, and peptides.

Nonpoint source: Nonpoint source pollutants are not traceable to a discrete origin, but generally result from land runoff, precipitation, drainage, or seepage.

Nutrient, available: That portion of an element or compound that can be readily absorbed and assimilated by growing plants.

Nutrient budget: An analysis of the nutrients entering a lake, discharging from the lake, and accumulating in the lake (e.g., input minus output = accumulation).

Nutrient inactivation: The process of rendering nutrients inactive by one of three methods: (1) Changing the form of a nutrient to make it unavailable to plants, (2) removing the nutrient from the photic zone, or (3) preventing the release or recycling of potentially available nutrients within a lake.

Oligotrophic lake: A lake with a small supply of nutrients, and consequently a low level of primary production. Oligotrophic lakes are often characterized by a high level of species diversification.

Orthophosphate: See phosphorus, available.

Outfall: The point where wastewater or drainage discharges from a sewer to a receiving body of water.

Overturn, turnovers: The complete mixing of a previously thermally stratified lake. This occurs in the spring and fall when water temperatures in the lake are uniform.

Oxygen deficit: The difference between observed oxygen concentrations and the amount that would be present at 100 percent saturation at a specific temperature.

Peak discharge: The maximum instantaneous flow from a given storm condition at a specific location.

Percolation test: A test used to determine the rate of percolation or seepage of water through natural soils. The percolation rate is expressed as time in minutes for a 1-inch fall of water in a test hold and is used to determine the acceptability of a site for treatment of domestic wastes by a septic system.

Perennial stream: A stream that maintains water in its channel throughout the year.

Periphyton: Microorganisms that are attached to or growing on submerged surfaces in a waterway.

Phosphorus, available: Phosphorus which is readily available for plant growth. Usually in the form of soluble orthophosphates.

Phosphorus, total (TP): All of the phosphorus present in a sample regardless of form. Usually measured by the persulfate digestion procedure.

Photic zone: The upper layer in a lake where sufficient light is available for photosynthesis.

Photosynthesis: The process occurring in green plants in which light energy is used to convert inorganic compounds to carbohydrates. In this process, carbon dioxide is consumed and oxygen is released.

Phytoplankton: Plant microorganisms, such as algae, living unattached in the water.

Plankton: Unattached aquatic microorganisms which drift passively through water.

Point source: A discreet pollutant discharge such as a pipe, ditch, channel, or concentrated animal feeding operation.

Population equivalent: An expression of the amount of a given waste load in terms of the size of human population that would contribute the same amount of biochemical oxygen demand (BOD) per day. A common base is 0.17 pounds (7.72 grams) of 5-day BOD per capita per day.

Primary production: The production of organic matter from light energy and inorganic materials, by autotrophic organisms.

Protozoa: Unicellular animals, including the ciliates and nonchlorophyllous flagellates.

Rainfall intensity: The rate at which rain falls, usually expressed in centimeters per hour.

Rational method: A means of computing peak storm drainage runoff (Q) by use of the formula Q = CIA, where C is a coefficient describing the physical drainage area, I is the average rainfall intensity, and A is the size of the drainage area.

Raw water: A water supply which is available for use but which has not yet been treated or purified.

Recurrence interval: The anticipated period in years that will elapse, based on average probability of storms in the design region, before a storm of a given intensity and/or total volume will recur; thus, a 10-year storm can be expected to occur on the average once every 10 years. Sewers are generally designed for a specific design storm frequency.

Riprap: Broken rock, cobbles, or boulders placed on earth surfaces, such as the face of a dam or the bank of a stream, for protection against the action of water (waves).

Saprophytic: Pertaining to those organisms that live on dead or decaying organic matter.

Scouring: The clearing and digging action of flowing water, especially the downward erosion caused by stream water in sweeping away mud and silt, usually during a flood.

Secchi depth: A measure of optical water clarity as determined by lowering a weighted Secchi disk into a water body to the point where it is no longer visible.

Sediment basin: A structure designed to slow the velocity of runoff water and facilitate the settling and retention of sediment and debris.

Sediment delivery ratio: The fraction of soil eroded from upland sources that reaches a continuous stream channel or storage reservoir.

Sediment discharge: The quantity of sediment, expressed as a dry weight or volume, transported through a stream cross-section in a given time. Sediment discharge consists of both suspended load and bedload.

Septic: A putrefactive condition produced by anaerobic decomposition of organic wastes, usually accompanied by production of malodorous gases.

Standing crop: The biomass present in a body of water at a particular time.

Sub-basin: A physical division of a larger basin, associated with one reach of the storm drainage system.

Substrate: The substance or base upon which an organism grows.

Suspended solids: Refers to the particulate matter in a sample, including the material that settles readily as well as the material that remains dispersed.

Swale: An elongated depression in the land surface that is at least seasonally wet, is usually heavily vegetated, and is normally without flowing water. Swales conduct stormwater into primary drainage channels and provide some groundwater recharge.

Terrace: An embankment or combination of an embankment and channel built across a slope to control erosion by diverting or storing surface runoff instead of permitting it to flow uninterrupted down the slope.

Thermal stratification: The layering of water bodies due to temperature-induced density differences.

Thermocline: See metalimnion.

Tile drainage: Land drainage by means of a series of tile lines laid at a specified depth and grade.

Total solids: The solids in water, sewage, or other liquids, including the dissolved, filterable, and nonfilterable solids. The residue left when a sample is evaporated and dried at a specified temperature.

Trace elements: Those elements which are needed in low concentrations for the growth of an organism.

Trophic condition: A relative description of a lake's biological productivity. The range of trophic conditions is characterized by the terms oligotrophic for the least biologically productive, to eutrophic for the most biologically productive.

Turbidity: A measure of the cloudiness of a liquid. Turbidity provides an indirect measure of the suspended solids concentration in water.

Urban runoff: Surface runoff from an urban drainage area.

Volatile solids: The quantity of solids in water, sewage, or other liquid, which is lost upon ignition at 600° C.

Waste load allocation: The assignment of target pollutant loads to point sources so as to achieve water quality standards in a stream segment in the most effective manner.

Water quality: A term used to describe the chemical, physical, and biological characteristics of water, usually with respect to its suitability for a particular purpose.

Water quality standards: State-enforced standards describing the required physical and chemical properties of water according to its designated uses.

Watershed: See drainage basin.

Weir: Device for measuring or regulating the flow of water.

Zooplankton: Protozoa and other animal microorganisms living unattached in water.

Appendix C

Water Quality Data

Project Name: LaGrange County

Project No.: 1206-01

Sample Information

Laboratory Sample Number	Date Collected	Date Received	Sample Type	Sample Source and Description
9798	08/18/90	08/20/90	Grab	Adams Top
9799	08/18/90	08/20/90	Grab	Adams Bottom
9800	08/18/90	08/20/90	Grab	Goose Top
9801	08/18/90	08/20/90	Grab	Goose Bottom

Test Results (mg/l unless specified)

Test Parameter	Sample Number 9798	Sample Number 9799	Sample Number 9800	Sample Number 9801
pH	8.5	7.6	8.9	7.4
Alkalinity, Total (CaC03)	128	152	106	152
Conductivity (Micromhos)	349	399	315	406
Nitrate/Nitrite (N)	<0.01	<0.01	<0.01	0.03
Ammonia (N)	N/A	N/A	N/A	N/A
Tot. Kjeldahl Nitrogen (N)	0.61	1.13	1.17	1.95
Total Phosphorus (P) (unfiltered)	0.0062	0.10	0.025	0.32
Orthophosphate (P) (filtered)	<0.01	0.052	<0.01	0.27
Total Suspended Solids	1.8	0.85	0.85	2.2

Lab Comments:

David L. Deaver

David Deaver
Laboratory Supervisor

DER Certification No. 52-264

ject Name: LaGrange County

ject No.: 1206-01

Sample Information

oratory Sample Number	Date Collected	Date Received	Sample Type	Sample Source and Description
9794	08/18/90	08/20/90	Grab	Atwood Top
9795	08/18/90	08/20/90	Grab	Atwood Bottom
9796	08/18/90	08/20/90	Grab	Loon Top
9797	08/18/90	08/20/90	Grab	Loon Bottom

Test Results (mg/l unless specified)

Test Parameter	Sample Number 9794	Sample Number 9795	Sample Number 9796	Sample Number 9797
I	8.7	7.5	8.5	7.6
lkalinity, Total (CaC03)	110	152	136	160
onductivity (Micromhos)	256	333	387	463
itrate/Nitrite (N)	<0.01	<0.01	0.23	0.70
nmonia (N)	N/A	N/A	N/A	N/A
ot. Kjeldahl Nitrogen (N)	0.73	1.67	1.17	1.86
otal Phosphorus (P) (unfiltered)	0.025	0.053	0.030	0.27
thophosphate (P) (filtered)	<0.01	<0.01	<0.01	0.17
otal Suspended Solids	0.68	0.92	6.7	1.2

Comments:

David Deaver
Laboratory Supervisor

R Certification No. 52-264

CHLOROPHYLL ANALYSES: 1990, ROUND 2

ALL VALUES GIVEN IN UG/L

STATION	DATE	CHL. A	PHAEO.	CHL+PHAEO
OLIN	AUG, 1990	1.2	.5	1.7
LOON	AUG, 1990	8.7	1.8	10.5
ADAMS	AUG, 1990	2.9	1.2	4.1
DALLAS	AUG, 1990	2.6	1.1	3.7
GOOSE	AUG, 1990	7.6	2.4	10.0
OLIVER	AUG, 1990	2.7	0.0	2.7
ATWOOD	AUG, 1990	3.0	1.2	4.2
WITMER	AUG, 1990	6.7	1.1	7.8
WESTLER	AUG, 1990	6.0	0.0	6.0
MESSICK	AUG, 1990	3.3	.3	3.6
HACKENBURG	AUG, 1990	3.8	1.0	4.8
MARTIN	AUG, 1990	3.5	0.0	3.5

LOON PHYTOPLANKTON 8/90

0 - 5 FT TOW

TAXON	CELLS/ML
BACILLARIOPHYTA	
Fragilaria	8.3
Melosira	5.3
Synedra	.9
CHRYSOPHYTA	
Dinobryon	3.3
CRYPTOPHYTA	
Cryptomonas	1.1
CYANOPHYTA	
Anabaena	435.8
Aphanizomenon	1434.7
Aphanothece	875.6
Lyngbya	194.0
Microcystis	353.2
Oscillatoria	29.8
PYRRHOPHYTA	
Ceratium	7.9
TOTAL	3350.5
BACILLARIOPHYTA	14.7
CHRYSOPHYTA	3.3
CRYPTOPHYTA	1.1
CYANOPHYTA	3323.3
PYRRHOPHYTA	7.9

TAXON	UG/L
BACILLARIOPHYTA	
Fragilaria	16.7
Melosira	1.6
Synedra	44.7
CHRYSOPHYTA	
Dinobryon	10.1
CRYPTOPHYTA	
Cryptomonas	1.1
CYANOPHYTA	
Anabaena	174.3
Aphanizomenon	71.7
Aphanothece	8.7
Lyngbya	388.0
Microcystis	70.6
Oscillatoria	.5
PYRRHOPHYTA	
Ceratium	1910.4
TOTAL	2698.9
BACILLARIOPHYTA	63.1
CHRYSOPHYTA	10.1
CRYPTOPHYTA	1.1
CYANOPHYTA	714.1
PYRRHOPHYTA	1910.4

LOON

TAXON	CELLS/ML
BACILLARIOPHYTA	
Fragilaria	4.1
Melosira	5.1
Synedra	.3
CRYPTOPHYTA	
Cryptomonas	1.2
CYANOPHYTA	
Anabaena	59.0
Aphanizomenon	151.5
Microcystis	143.5
TOTAL	364.9
BACILLARIOPHYTA	9.5
CRYPTOPHYTA	1.2
CYANOPHYTA	354.0

TAXON	UG/L
BACILLARIOPHYTA	
Fragilaria	8.2
Melosira	1.5
Synedra	.2
CRYPTOPHYTA	
Cryptomonas	1.2
CYANOPHYTA	
Anabaena	23.6
Aphanizomenon	7.5
Microcystis	28.7
TOTAL	71.2
BACILLARIOPHYTA	10.0
CRYPTOPHYTA	1.2
CYANOPHYTA	59.8

GOOSE PHYTOPLANKTON 8/90

0 - 5 FT TOW

TAXON	CELLS/ML
BACILLARIOPHYTA	
Melosira	1.7
CHLOROPHYTA	
Staurastrum	.1
CRYPTOPHYTA	
Cryptomonas	.2
CYANOPHYTA	
Anabaena	492.7
Aphanizomenon	1127.2
Lyngbya	28.3
Microcystis	367.2
Oscillatoria	116.7
PYRRHOPHYTA	
Ceratium	.2
TOTAL	2134.7
BACILLARIOPHYTA	1.7
CHLOROPHYTA	.1
CRYPTOPHYTA	.2
CYANOPHYTA	2132.3
PYRRHOPHYTA	.2

TAXON	UG/L
BACILLARIOPHYTA	
Melosira	.5
CHLOROPHYTA	
Staurastrum	1.6
CRYPTOPHYTA	
Cryptomonas	.2
CYANOPHYTA	
Anabaena	197.1
Aphanizomenon	56.3
Lyngbya	56.7
Microcystis	73.4
Oscillatoria	2.3
PYRRHOPHYTA	
Ceratium	64.8
TOTAL	453.1
BACILLARIOPHYTA	.5
CHLOROPHYTA	1.6
CRYPTOPHYTA	.2
CYANOPHYTA	385.9
PYRRHOPHYTA	64.8

TAXON	CELLS/ML
BACILLARIOPHYTA	
Melosira	3.2
CRYPTOPHYTA	
Cryptomonas	.3
CYANOPHYTA	
Anabaena	110.9
Aphanizomenon	511.4
Lyngbya	37.6
Microcystis	67.5
Oscillatoria	254.7
PYRRHOPHYTA	
Ceratium	.1
TOTAL	986.2
BACILLARIOPHYTA	3.2
CRYPTOPHYTA	.3
CYANOPHYTA	982.3
PYRRHOPHYTA	.1

TAXON	UG/L
BACILLARIOPHYTA	
Melosira	7.8
CRYPTOPHYTA	
Cryptomonas	.3
CYANOPHYTA	
Anabaena	44.3
Aphanizomenon	25.5
Lyngbya	75.2
Microcystis	13.5
Oscillatoria	5.0
PYRRHOPHYTA	
Ceratium	46.3
TOTAL	218.4
BACILLARIOPHYTA	7.8
CRYPTOPHYTA	.3
CYANOPHYTA	163.8
PYRRHOPHYTA	46.3

COOPERATIVE VENTURES, INC.
NALYTICAL TESTING LABORATORY
P.O. BOX 796
EASTON, PA 18044-0796
(215) 258-2911

ANALYTICAL REPORT NO.: P53-26725.0
DATE: 09/24/90
SAMPLE NOS: P53-241-535-546
RECEIVED: 08/29/90
SAMPLED BY: CUSTOMER

ORT TO:

F.X. BROWNE ASSOCIATES, INC
220 SOUTH BROAD STREET
P.O. BOX 401
LANSDALE, PA. 19446

Joseph P. Merlo
JOSEPH P. MERLO, TECHNICAL DIRECTOR

PLE INFORMATION I LOG#:		IDENTIFICATION	SAMPLE DATE:	TIME:
5	=	GOOSE	08/28	NOT GIVEN
6	=	LOON	08/28	NOT GIVEN

VI TEST ALYSIS:	COMPLETED BY:	DATE:	UNITS	RESULTS 535	536
SOLIDS	JM	09/20	%	23.11	23.77
VOLATILE SOLDIS	JM	09/20	%	11.31	11.47
OTAL PHOSPHORUS	CT	09/06	mg/kg	557	630
OTAL NITROGEN	CT	09/17	mg/kg	20.9	18.6

Particle size distribution to follow under seperate cover

PLE INFORMATION I LOG#:		IDENTIFICATION	SAMPLE DATE:	TIME:
7	=	MARTIN	08/28	NOT GIVEN
8	=	OLIVER (EAST)	08/28	NOT GIVEN

TEST ALYSIS:	COMPLETED BY:	DATE:	UNITS	RESULTS 537	538
SOLIDS	JM	09/20	%	36.63	76.4
VOLATILE SOLDIS	JM	09/20	%	15.52	1.2
OTAL PHOSPHORUS	CT	09/06	mg/kg	1569	12.3
OTAL NITROGEN	CT	09/17	mg/kg	13.7	10.9

COOPERATIVE VENTURES, INC.
ANALYTICAL TESTING LABORATORY
P.O. BOX 796
EASTON, PA 18044-0796
(215) 258-2911

ANALYTICAL REPORT NO.:	P53.26950.0
DATE:	09/26/90
SAMPLE NOS:	P53-241-535/54
RECEIVED:	08/29/90
SAMPLED BY:	CVI

REPORT TO:

F.X. BROWNE ASSOC., INC.
220 SOUTH BROAD STREET
LANSDALE, PA 19446

1222-01

JOSEPH P. MERLO, TECHNICAL DIRECTOR

SAMPLE ID CVI LOG:	IDENTIFICATION:	SAMPLE DATE:	TIME:
SEDIMENT SAMPLES FROM LAKES			
535	= GOOSE	NOT GIVEN	NOT GIVEN

PARTICLE-SIZE ANALYSIS OF SOILS ASTM D422 (HYDROMETER)

% Retained on # 200 sieve = 2.0% Starting Time: 1000

% passing # 10 seive 100%

FINE SAND	2.0%
SILT	98.0%
CLAY	< 1.0%
COLLOIDS	< 1.0%

Temp.C.	% soil in suspension	Time	D (mm)
25	67.8	2 mins	0.0327
25	64.6	5 mins	0.0207
25	41.9	15 mins	0.0125
25	33.9	30 mins	0.0095
25	27.5	60 mins	0.0064
25	22.6	250 mins	0.0032
25	16.1	24 hrs	0.0013

TECH/DATE: CT/ 09-25

COOPERATIVE VENTURES, INC.
NALYTICAL TESTING LABORATORY
P.O. BOX 796
EASTON, PA 18044-0796
(215) 258-2911

ANALYTICAL REPORT NO.: P53.26950.0
DATE: 09/26/90
SAMPLE NOS: P53-241-535/546
RECEIVED: 08/29/90
SAMPLED BY: CVI

RT TO:

F.X. BROWNE ASSOC., INC.
220 SOUTH BROAD STREET
LANSDALE, PA 19446

1222-01

JOSEPH P. MERLO, TECHNICAL DIRECTOR

LE ID I LOG:	IDENTIFICATION:	SAMPLE DATE:	TIME:
MENT SAMPLES FROM LAKES			
5 =	LOON	NOT GIVEN	NOT GIVEN

PARTICLE-SIZE ANALYSIS OF SOILS ASTM D422 (HYDROMETER)

tained on # 200 sieve = 4.57% Starting Time: 0900

% passing # 10 seive 100%

FINE SAND	4.6%
SILT	95.4%
CLAY	< 1.0%
COLLOIDS	< 1.0%

).C.	% soil in suspension	Time	D (mm)
5	52.8	2 mins	0.0325
5	40.5	5 mins	0.0212
5	35.6	15 mins	0.0124
5	31.9	30 mins	0.0088
5	27.0	60 mins	0.0199
5	24.6	250 mins	0.0031
5	19.6	24 hrs	0.0013

'DATE: CT/ 09-25

Project Name: LaGrange County

Project No.: 1206-01

Sample Information

Laboratory Sample Number	Date Collected	Date Received	Sample Type	Sample Source and Description
9755	08/14/90	08/16/90	Grab	Dove Creek Duplicate
9756	08/14/90	08/16/90	Grab	Westler Outlet
9757	08/14/90	08/16/90	Grab	Goose Outlet
9758	08/14/90	08/16/90	Grab	Loon Out. Replicate

Test Results (mg/l unless specified)

Test Parameter	Sample Number 9755	Sample Number 9756	Sample Number 9757	Sample Number 9758
pH	7.7	8.1	8.6	8.3
Alkalinity, Total (CaC03)	294	178	108	148
Conductivity (Micromhos)	672	412	315	410
Nitrate/Nitrite (N)	0.23	1.25	0.037	0.51
Ammonia (N)	0.15	<0.1	<0.1	<0.1
Tot. Kjeldahl Nitrogen (N)	1.06	0.60	0.90	0.82
Total Phosphorus (P) (unfiltered)	0.35	<0.01	0.04	0.13
Orthophosphate (P) (filtered)	0.024	<0.01	<0.01	<0.01
Total Suspended Solids	24	4	3.4	13

Lab Comments:

David L. Deaver

David Deaver
Laboratory Supervisor

DER Certification No. 52-264

ject Name: **LaGrange County**

ject No.: **1206-01**

Sample Information

oratory Sample Number	Date Collected	Date Received	Sample Type	Sample Source and Description
9759	08/14/90	08/16/90	Grab	Old Lake Ditch
9760	08/14/90	08/16/90	Grab	Messick 550 S
9761	08/14/90	08/16/90	Grab	Adams Inlet
9762	08/14/90	08/16/90	Grab	Loon Outlet

Test Results (mg/l unless specified)

Test Parameter	Sample Number 9759	Sample Number 9760	Sample Number 9761	Sample Number 9762
H	8.1	7.3	8.3	8.4
lkalinity, Total (CaC03)	174	232	134	152
onductivity (Micromhos)	431	521	349	414
itrate/Nitrite (N)	<0.01	2.09	0.029	0.011
mmonia (N)	<0.1	0.35	0.18	<0.1
ot. Kjeldahl Nitrogen (N)	1.17	1.46	1.13	0.84
otal Phosphorus (P) (unfiltered)	0.17	0.64	0.03	0.12
rthophosphate (P) (filtered)	<0.01	0.18	<0.01	<0.01
otal Suspended Solids	12	4.2	8.0	4.5

Comments:

David L. Deaver

David Deaver
Laboratory Supervisor

R Certification No. 52-264

Project Name: LaGrange County

Project No.: 1206-01

Sample Information

Laboratory Sample Number	Date Collected	Date Received	Sample Type	Sample Source and Description
9763	08/14/90	08/16/90	Grab	Goose NW Inlet
9764	08/14/90	08/16/90	Grab	Wolcotville Duplct.
9765	08/14/90	08/16/90	Grab	Olin Inlet from Martin
9766	08/14/90	08/16/90	Grab	Witmer Outlet

Test Results (mg/l unless specified)

Test Parameter	Sample Number 9763	Sample Number 9764	Sample Number 9765	Sample Number 9766
pH	8.4	7.9	8.2	8.2
Alkalinity, Total (CaC03)	114	200	234	176
Conductivity (Micromhos)	318	441	531	415
Nitrate/Nitrite (N)	0.49	0.055	0.30	0.047
Ammonia (N)	<0.1	<0.1	<0.1	<0.1
Tot. Kjeldahl Nitrogen (N)	0.88	0.75	0.051	0.17
Total Phosphorus (P) (unfiltered)	0.16	0.08	0.14	0.014
Orthophosphate (P) (filtered)	<0.01	<0.01	<0.01	<0.01
Total Suspended Solids	5.5	24	4.7	0.43

Lab Comments:

David L. Deaver

David Deaver
Laboratory Supervisor

PaDER Certification No. 52-264

ject Name: **LaGrange County**

ject No.: **1206-01**

Sample Information

oratory Sample Number	Date Collected	Date Received	Sample Type	Sample Source and Description
9771	08/14/90	08/16/90	Grab	Martin SE Inlet
9772	08/14/90	08/16/90	Grab	Messick Inlet
9773	08/14/90	08/16/90	Grab	Dallas Outlet
9774	08/14/90	08/16/90	Grab	Winters Ditch

Test Results (mg/l unless specified)

Test Parameter	Sample Number 9771	Sample Number 9772	Sample Number 9773	Sample Number 9774
H	8.0	7.9	8.3	7.4
lkalinity, Total (CaC03)	276	162	170	188
onductivity (Micromhos)	609	408	417	481
itrate/Nitrite (N)	0.90	0.98	0.11	0.39
mmonia (N)	0.13	<0.1	<0.1	0.15
ot. Kjeldahl Nitrogen (N)	0.30	0.30	0.35	1.26
otal Phosphorus (P) (unfiltered)	0.058	0.17	0.19	0.23
rthophosphate (P) (filtered)	<0.01	<0.01	<0.01	0.042
otal Suspended Solids	5.4	6.2	0.37	3.1

Comments:

David G. Deaver

David Deaver
Laboratory Supervisor

ER Certification No. 52-264

Project Name: LaGrange County

Project No.: 1206-01

Sample Information

Laboratory Sample Number	Date Collected	Date Received	Sample Type	Sample Source and Description
9775	08/14/90	08/16/90	Grab	Oliver East
9776	08/14/90	08/16/90	Grab	Oliver Outlet
9777	08/14/90	08/16/90	Grab	Witmer SE Inlet
9778	08/14/90	08/16/90	Grab	Friskney Ditch

Test Results (mg/l unless specified)

Test Parameter	Sample Number 9775	Sample Number 9776	Sample Number 9777	Sample Number 9778
pH	8.0	8.1	7.9	7.2
Alkalinity, Total ($CaCO_3$)	278	158	192	110
Conductivity (Micromhos)	643	402	457	312
Nitrate/Nitrite (N)	0.58	0.058	0.98	0.92
Ammonia (N)	<0.1	<0.1	0.12	<0.1
Tot. Kjeldahl Nitrogen (N)	0.33	0.26	0.60	1.03
Total Phosphorus (P) (unfiltered)	0.21	0.12	0.16	0.44
Orthophosphate (P) (filtered)	<0.01	<0.01	0.024	0.20
Total Suspended Solids	16	6.3	29	42

Lab Comments:

David D Deaver

David Deaver
Laboratory Supervisor

DER Certification No. 52-264

ject Name: LaGrange County

ject No.: 1206-01

Sample Information

oratory Sample Number	Date Collected	Date Received	Sample Type	Sample Source and Description
9779	08/14/90	08/16/90	Grab	Hackenburg 550 S.
9780	08/14/90	08/16/90	Grab	Martin NE Inlet
9781	08/14/90	08/16/90	Grab	Messick Outlet
9782	08/14/90	08/16/90	Grab	Goose SE Inlet

Test Results (mg/l unless specified)

Test Parameter	Sample Number 9779	Sample Number 9780	Sample Number 9781	Sample Number 9782
I	7.8	8.2	8.2	7.2
,kalinity, Total (CaC03)	156	230	166	174
onductivity (Micromhos)	393	544	404	247
.trate/Nitrite (N)	1.0	0.83	0.6	0.27
nmonia (N)	<0.1	<0.1	<0.1	<0.1
ot. Kjeldahl Nitrogen (N)	0.26	0.53	0.38	0.69
otal Phosphorus (P) 'unfiltered)	0.073	0.084	0.27	0.52
'thophosphate (P) 'filtered)	<0.01	<0.01	<0.01	0.35
otal Suspended Solids	7.2	1.4	8.6	73

Comments:

David H. Deaver

David Deaver
Laboratory Supervisor

R Certification No. 52-264

MMM-01 1000-2

AUG 24 1990

MM

FXB

HML HOOSIER MICROBIOLOGICAL LABORATORY

912 West McGalliard Muncie, Indiana 47303-1702 1-317-288-1124

August 20, 1990

Michael Martin
F. X. Browne Associates
220 South Broad St.
Lansdale, PA 19446

Re: Lake Sample in LaGrange County

Dear Mr. Martin:

The following are the result(s) of the test(s) performed on the sample(s) received 8-14-90:

SAMPLE(S)	TEST(S)-SM* Method	RESULT(S)	DATE COMPLETED
Witmer	Fecal Coliform-909C	370,000/100 ml	8-15-90
NE Inlet	Fecal Streptococci-910B	<1/100 ml	8-16-90
	Fecal Coliform-909C	32,000/100 ml	8-15-90
Wolcottville	Fecal Streptococci-910B	<1/100 ml	8-16-90
Goose	Fecal Coliform-909C	13,000/100 ml	8-15-90
NW Inlet	Fecal Streptococci-910B	20/100 ml	8-16-90
Goose	Fecal Coliform-909C	282,000/100 ml	8-15-90
SE Inlet	Fecal Streptococci-910B	20/100 ml	8-16-90
Dallas	Fecal Coliform-909C	27/100 ml	8-15-90
Outlet	Fecal Streptococci-910B	<1/100 ml	8-16-90
Old Lake	Fecal Coliform-909C	70/100 ml	8-15-90
Ditch	Fecal Streptococci-910B	10/100 ml	8-16-90
Adams	Fecal Coliform-909C	190,000/100 ml	8-15-90
Inlet	Fecal Streptococci-910B	10/100 ml	8-16-90
Loon Outlet	Fecal Coliform-909C	100/100 ml	8-15-90
Duplicate	Fecal Streptococci-910B	<1/100 ml	8-16-90

F. X. Browne Associates cont.
August 20, 1990
Page 2

SAMPLE(S)	TEST(S)-SM* Method	RESULT(S)	DATE COMPLETED
Messick Outlet	Fecal Coliform-909C Fecal Streptococci-910B	15/100 ml 30/100 ml	8-15-90 8-16-90
Messick 550 S.	Fecal Coliform-909C Fecal Streptococci-910B	197,000/100 ml 10/100 ml	8-15-90 8-16-90
Hack 75 W.	Fecal Coliform-909C Fecal Streptococci-910B	250/100 ml <1/100 ml	8-15-90 8-16-90
Westler 125 E.	Fecal Coliform-909C Fecal Streptococci-910B	9,100/100 ml 10/100 ml	8-15-90 8-16-90
Oliver East	Fecal Coliform-909C Fecal Streptococci-910B	2,300/100 ml <1/100 ml	8-15-90 8-16-90
Martin NE Inlet	Fecal Coliform-909C Fecal Streptococci-910B	297,000/100 ml 50/100 ml	8-15-90 8-16-90
Olin Inlet from Martin	Fecal Coliform-909C Fecal Streptococci-910B	760/100 ml 10/100 ml	8-15-90 8-16-90
Oliver Inlet from Olin	Fecal Coliform-909C Fecal Streptococci-910B	2/100 ml 20/100 ml	8-15-90 8-16-90
Westler ~~Webster~~ Outlet	Fecal Coliform-909C Fecal Streptococci-910B	9/100 ml <1/100 ml	8-15-90 8-16-90
Winters Ditch	Fecal Coliform-909C Fecal Streptococci-910B	71,000/100 ml 40/100 ml	8-15-90 8-16-90
Martin SE Inlet	Fecal Coliform-909C Fecal Streptococci-910B	128,000/100 ml 100/100 ml	8-15-90 8-16-90
Wolcottville Duplicate	Fecal Coliform-909C Fecal Streptococci-910B	30,000/100 ml 10/100 ml	8-15-90 8-16-90
Adams Outlet	Fecal Coliform-909C Fecal Streptococci-910B	82/100 ml 20/100 ml	8-15-90 8-16-90
Oliver Out	Fecal Coliform-909C Fecal Streptococci-910B	12/100 ml 10/100 ml	8-15-90 8-16-90
Dove Creek	Fecal Coliform-909C Fecal Streptococci-910B	18,000/100 ml <1/100 ml	8-15-90 8-16-90

SAMPLE(S)	TEST(S)-SM* Method	RESULT(S)	DATE COMPLETED
Witmer Outlet	Fecal Coliform-909C	110/100 ml	8-15-90
	Fecal Streptococci-910B	70/100 ml	8-16-90
Atwood Outlet	Fecal Coliform-909C	39/100 ml	8-15-90
	Fecal Streptococci-910B	50/100 ml	8-16-90
Goose Outlet	Fecal Coliform-909C	1,700/100 ml	8-15-90
	Fecal Streptococci-910B	160/100 ml	8-16-90
Loon Outlet	Fecal Coliform-909C	200/100 ml	8-15-90
	Fecal Streptococci-910B	<1/100 ml	8-16-90
Witmer SE Inlet	Fecal Coliform-909C	207,000/100 ml	8-15-90
	Fecal Streptococci-910B	30/100 ml	8-16-90
Hack 550 S.	Fecal Coliform-909C	9,000/100 ml	8-15-90
	Fecal Streptococci-910B	10/100 ml	8-16-90
Dove Creek Duplicate	Fecal Coliform-909C	100/100 ml	8-15-90
	Fecal Streptococci-910B	<1/100 ml	8-16-90
Messick Inlet	Fecal Coliform-909C	18/100 ml	8-15-90
	Fecal Streptococci-910B	10/100 ml	8-16-90
Friskney Ditch	Fecal Coliform-909C	60/100 ml	8-15-90
	Fecal Streptococci-910B	10/100 ml	8-16-90

*Standard Methods for the Examination of Water and Wastewater

This test was performed by L.N. Please feel free to contact us if we can be of further service to you.

Sincerely,

Donald A. Hendrickson

Donald A. Hendrickson, Ph.D.
Hoosier Microbiological Lab.

DAH/akg

Sample Information

oratory Sample Number	Date Collected	Date Received	Sample Type	Sample Source and Description
0485	10/04/90	10/05/90	Grab	Goose Outlet
0486	10/04/90	10/05/90	Grab	Loon Outlet
0487	10/04/90	10/05/90	Grab	Goose Lake #2
0488	10/04/90	10/05/90	Grab	Friskney Ditch

Test Results (mg/l unless specified)

Test Parameter	Sample Number 0485	Sample Number 0486	Sample Number 0487	Sample Number 0488
H	7.7	8.0	7.0	7.4
lkalinity, Total (CaC03)	126	160	248	144
onductivity (Micromhos)	362	448	650	505
itrate/Nitrite (N)	<0.01	<0.01	2.23	3.19
mmonia (N)	<0.1	<0.1	0.27	<0.1
ot. Kjeldahl Nitrogen (N)	0.99	0.80	1.94	1.78
otal Phosphorus (P) (unfiltered)	0.044	0.057	0.367	0.498
rthophosphate (P) (filtered)	0.002	0.001	0.222	0.230
ecal Coliform (No./100 ml)	<2			<2
ecal Streptococci (No./100ml)	160			2542
otal Suspended Solids	1.4	5.6	4.4	78.9

Comments: ______________________________

Dave Deaver

David Deaver
Laboratory Supervisor

ER Certification No. 52-264

Sample Information

Laboratory Sample Number	Date Collected	Date Received	Sample Type	Sample Source and Description
0493	10/04/90	10/05/90	Grab	Goose Lake #3
0494	10/04/90	10/05/90	Grab	Winters Ditch
0495	10/04/90	10/05/90	Grab	Old Lake Ditch
0599	10/04/90	10/05/90	Grab	Undetermined

Test Results (mg/l unless specified)

Test Parameter	Sample Number 0493	Sample Number 0494	Sample Number 0495	Sample Number 0599
pH	7.8	7.2	7.9	
Alkalinity, Total (CaC03)	128	212	196	
Conductivity (Micromhos)	335	575	466	
Nitrate/Nitrite (N)	<0.01	3.19	0.20	
Ammonia (N)	<0.1	0.13	<0.1	
Tot. Kjeldahl Nitrogen (N)	1.09	2.28	1.29	
Total Phosphorus (P) (unfiltered)	0.075	0.348	0.056	
Orthophosphate (P) (filtered)	0.029	0.200	0.027	
Fecal Coliform (No./100 ml)	<2	<2	<2	<2
Fecal Streptococci (No./100ml)	366	1120	224	140
Total Suspended Solids	1.0	12.9	10.3	

Lab Comments:

Dave Deaver

David Deaver
Laboratory Supervisor

PaDER Certification No. 52-264

Sample Information

boratory Sample Number	Date Collected	Date Received	Sample Type	Sample Source and Description
0489	10/04/90	10/05/90	Grab	Goose NW Inlet
0490	10/04/90	10/05/90	Grab	Loon Lake #1
0491	10/04/90	10/05/90	Grab	Loon Lake #2
0492	10/04/90	10/05/90	Grab	Goose SE Inlet

Test Results (mg/l unless specified)

Test Parameter	Sample Number 0489	Sample Number 0490	Sample Number 0491	Sample Number 0492
pH	7.4	7.7	7.0	7.2
lkalinity, Total (CaC03)	116	296	228	86
onductivity (Micromhos)	336	658	696	331
itrate/Nitrite (N)	1.00	0.88	5.23	1.52
mmonia (N)	0.10	<0.1	0.13	<0.1
ot. Kjeldahl Nitrogen (N)	1.04	0.59	2.59	2.76
otal Phosphorus (P) (unfiltered)	0.367	0.150	0.167	1.709
rthophosphate (P) (filtered)	0.090	0.029	0.054	0.467
ecal Coliform (No./100 ml)	<2			
ecal Streptococci (No./100ml)	2260			
otal Suspended Solids	87.1	26.5	16.7	703.1

Comments:

Dave Deaver
David Deaver
Laboratory Supervisor

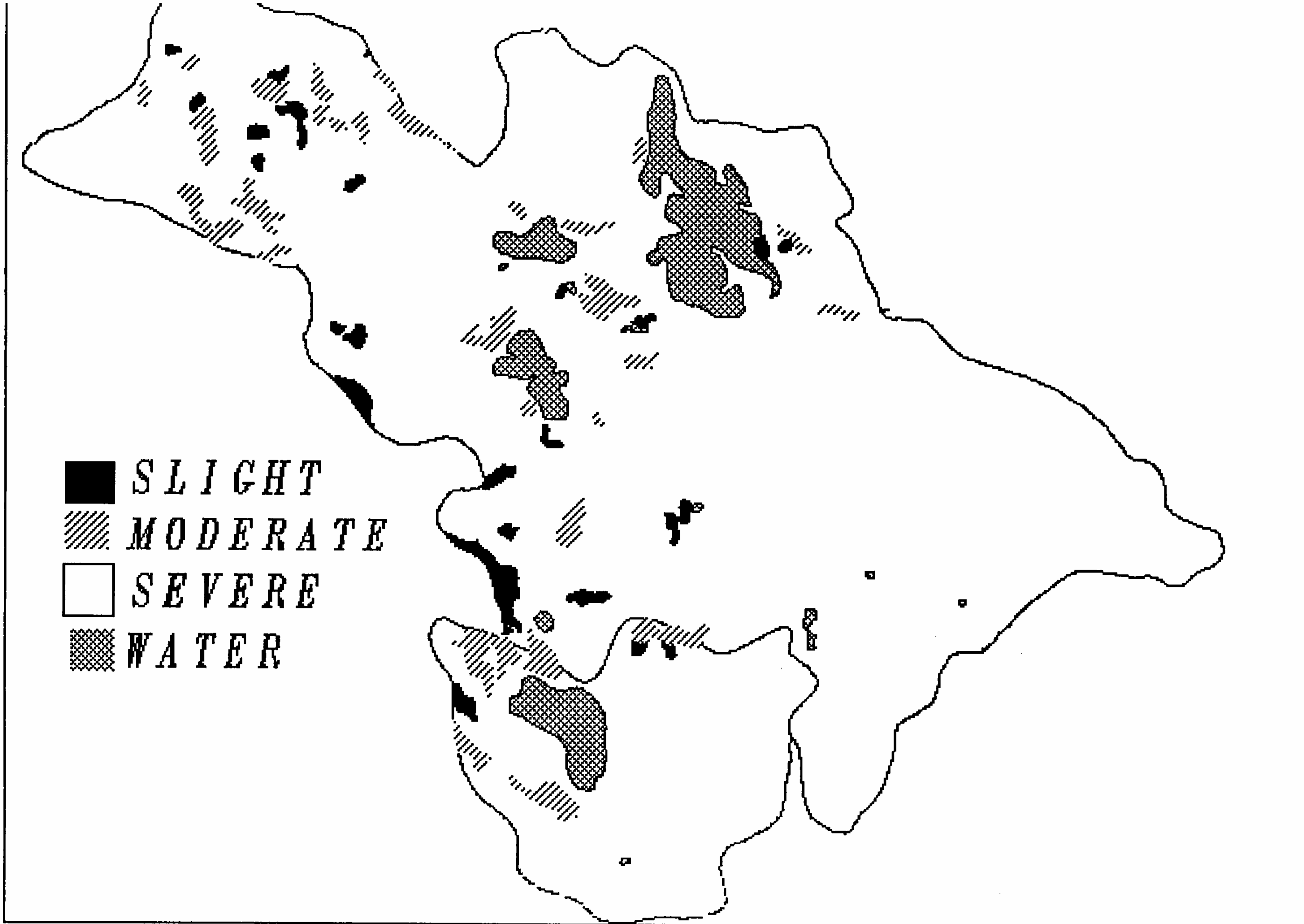
ER Certification No. 52-264

Appendix D

Macrophyte Maps and Sediment Thickness Profiles

Appendix E

Results of AGNPS Model



Limitations of soils for subsurface disposal

FXB GIS

Watershed Summary

Watershed Studied	Loon Lake
The area of the watershed is	5360 acres
The area of each cell is	40.00 acres
The characteristic storm precipitation is	2.30 inches
The storm energy-intensity value is	16

Values at the Watershed Outlet

Cell number	18 200
Runoff volume	1.0 inches
Peak runoff rate	1240 cfs
Total Nitrogen in sediment	0.08 lbs/acre
Total soluble Nitrogen in runoff	2.89 lbs/acre
Soluble Nitrogen concentration in runoff	12.67 ppm
Total Phosphorus in sediment	0.04 lbs/acre
Total soluble Phosphorus in runoff	0.59 lbs/acre
Soluble Phosphorus concentration in runoff	2.61 ppm
Total soluble chemical oxygen demand	18.90 lbs/acre
Soluble chemical oxygen demand concentration in runoff	83 ppm

Feedlot Analysis

Cell # 16 000

Nitrogen concentration (ppm)	144.000
Phosphorus concentration (ppm)	34.680
COD concentration (ppm)	1800.000
Nitrogen mass (lbs)	8.329
Phosphorus mass (lbs)	2.006
COD mass (lbs)	104.107

Animal feedlot rating number 0

Feedlot Analysis

Cell # 85 000

Nitrogen concentration (ppm)	144.000
Phosphorus concentration (ppm)	34.680
COD concentration (ppm)	1800.000
Nitrogen mass (lbs)	8.329
Phosphorus mass (lbs)	2.006
COD mass (lbs)	104.107

Animal feedlot rating number 0

Feedlot Analysis

Cell # 97 000

Nitrogen concentration (ppm)	300.000
Phosphorus concentration (ppm)	62.560
COD concentration (ppm)	4500.000
Nitrogen mass (lbs)	17.351
Phosphorus mass (lbs)	3.618
COD mass (lbs)	260.268

Animal feedlot rating number 10

Feedlot Analysis

Cell # 113 000

Nitrogen concentration (ppm)	300.000
Phosphorus concentration (ppm)	85.000
COD concentration (ppm)	4500.000
Nitrogen mass (lbs)	11.235
Phosphorus mass (lbs)	3.183
COD mass (lbs)	168.527

Animal feedlot rating number 5

Feedlot Analysis

Cell # 120 000

Nitrogen concentration (ppm)	144.000
Phosphorus concentration (ppm)	34.680
COD concentration (ppm)	1800.000
Nitrogen mass (lbs)	8.329
Phosphorus mass (lbs)	2.006
COD mass (lbs)	104.107

Animal feedlot rating number 0

Feedlot Analysis

Cell # 121 000

Nitrogen concentration (ppm)	62.400
Phosphorus concentration (ppm)	18.360
COD concentration (ppm)	612.000
Nitrogen mass (lbs)	3.609
Phosphorus mass (lbs)	1.062
COD mass (lbs)	35.396

Animal feedlot rating number 0

Feedlot Analysis

Cell # 122 000

Nitrogen concentration (ppm)	144.000
Phosphorus concentration (ppm)	34.680
COD concentration (ppm)	1800.000
Nitrogen mass (lbs)	8.329
Phosphorus mass (lbs)	2.006
COD mass (lbs)	104.107

Animal feedlot rating number 0

Sediment Analysis

Particle type	Area Weighted Erosion Upland (t/a)	Area Weighted Erosion Channel (t/a)	Delivery Ratio (%)	Enrichment Ratio	Mean Concentration (ppm)	Area Weighted Yield (t/a)	Yield (tons)
CLAY	0.03	0.00	42	17	98.58	0.01	60.2

SILT	0.04	0.00	1	0	3.50	0.00	2.1
SAGG	0.24	0.00	0	0	0.81	0.00	0.5
LAGG	0.15	0.00	0	0	2.73	0.00	1.7
SAND	0.04	0.00	0	0	0.86	0.00	0.5
TOTAL	0.49	0.00	2	1	106.48	0.01	65.0

-HYDR- Cell Num Div	Drainage Area (acres)	Overland Runoff (in.)	Upstream Runoff (in.)	Peak Flow Upstream (cfs)	Downstream Runoff (in.)	Peak Flow Downstream (cfs)
1 000	40	1.02	0.00	0	1.02	82
2 000	40	1.02	0.00	0	1.02	78
3 000	80	0.66	1.02	75	0.84	78
4 000	80	0.85	1.02	75	0.94	86
5 000	40	1.02	0.00	0	1.02	83
6 000	40	1.02	0.00	0	1.02	89
7 000	40	1.02	0.00	0	1.02	87
8 000	40	1.02	0.00	0	1.02	82
9 000	40	1.02	0.00	0	1.02	69
10 000	40	1.02	0.00	0	1.02	87
11 000	120	1.02	0.84	85	0.90	112
12 000	440	0.00	0.90	275	0.00	0
13 000	80	0.00	1.02	76	0.00	0
14 000	40	1.02	0.00	0	1.02	88
15 000	120	1.02	1.02	156	1.02	136
16 000	80	1.02	1.02	85	1.02	114
17 000	120	1.02	1.02	114	1.02	130
18 100	130	1.02	1.02	130	1.02	122
18 200	5360	2.30	1.00	1251	1.01	1240
18 300	10	1.02	0.00	0	1.02	33
18 400	5180	2.30	1.00	927	1.00	914
19 000	80	1.02	1.02	78	1.02	93
20 000	200	0.66	0.94	171	0.89	172
21 000	40	1.02	0.00	0	1.02	87
22 000	160	1.02	1.02	221	1.02	189
23 000	40	1.02	0.00	0	1.02	89
24 000	160	1.02	1.02	147	1.02	160
25 000	40	1.02	0.00	0	1.02	87
26 000	80	1.02	1.02	90	1.02	111
27 000	120	1.02	1.02	102	1.02	121
28 100	10	1.02	0.00	0	1.02	33
28 200	5160	2.30	1.00	941	1.00	926
28 300	130	1.02	1.02	121	1.02	115
28 400	5140	2.30	1.00	949	1.00	939
29 100	10	2.30	0.00	0	2.30	63
29 200	20	0.71	0.71	24	0.71	32
29 300	4980	2.30	0.99	1348	0.99	1333
29 400	30	2.30	0.71	21	1.24	42
30 100	10	0.71	0.00	0	0.71	23
30 200	10	0.71	0.00	0	0.71	25
30 300	10	2.30	0.00	0	2.30	52
30 400	20	0.71	0.71	21	0.71	25
31 000	40	1.02	0.00	0	1.02	80
32 000	40	1.02	0.00	0	1.02	84
33 000	80	0.71	1.02	80	0.86	93
34 000	80	1.02	1.02	87	1.02	117
35 000	280	1.02	1.02	274	1.02	260
36 000	40	1.02	0.00	0	1.02	90
37 000	200	1.02	1.02	154	1.02	174
38 100	210	1.02	1.02	168	1.02	165
38 200	10	1.02	0.00	0	1.02	33
38 300	220	1.02	1.02	168	1.02	166
38 400	240	1.28	1.02	156	1.03	157
39 100	10	1.02	0.00	0	1.02	33
39 200	10	0.36	0.00	0	0.36	15
39 300	20	1.02	1.02	29	1.02	36
39 400	20	1.02	0.36	9	0.69	20
40 100	10	1.02	0.00	0	1.02	34
40 200	10	1.02	0.00	0	1.02	25
40 300	20	0.66	1.02	30	0.84	32
40 400	20	0.36	1.02	29	0.69	26
41 100	10	0.36	0.00	0	0.36	12
41 200	20	1.59	0.36	9	0.98	30
41 300	10	0.66	0.00	0	0.66	23
41 400	20	1.02	0.66	17	0.84	27
42 000	4930	2.30	0.98	923	0.99	924
43 100	130	2.30	1.05	102	1.15	104
43 200	90	0.75	1.02	97	0.99	84
43 300	2210	2.30	0.94	640	0.94	636
43 400	10	0.66	0.00	0	0.66	17
44 000	80	1.02	1.02	58	1.02	78
45 000	40	1.02	0.00	0	1.02	85
46 000	320	1.02	1.02	270	1.02	277
47 000	400	1.02	1.02	292	1.02	290
48 000	760	1.02	0.93	428	0.94	417
49 100	780	1.02	0.94	371	0.94	360
49 200	1070	1.02	0.96	453	0.96	435
49 300	770	1.02	0.94	459	0.94	444
49 400	40	1.02	1.02	44	1.02	48
50 100	1370	2.30	1.03	388	1.04	383
50 200	1420	2.30	1.03	391	1.04	383
50 300	270	1.02	1.28	191	1.27	188
50 400	20	1.02	1.02	32	1.02	40
51 100	1460	2.30	1.04	502	1.05	492
51 200	1500	0.36	1.04	611	1.04	594
51 300	10	1.02	0.00	0	1.02	34
51 400	10	1.02	0.00	0	1.02	35
52 100	1510	1.02	1.04	643	1.04	629
52 200	1530	1.59	1.04	411	1.04	404
52 300	10	1.02	0.00	0	1.02	29
52 400	10	1.02	0.00	0	1.02	31
53 000	2530	2.30	0.98	527	1.00	536
54 100	2190	2.30	0.93	498	0.94	494
54 200	2180	0.66	0.93	653	0.93	643
54 300	10	1.02	0.00	0	1.02	26
54 400	2170	0.66	0.93	460	0.93	453
55 000	2160	1.02	0.93	801	0.93	800
56 000	40	1.02	0.00	0	1.02	87
57 000	80	1.02	1.02	80	1.02	107
58 000	120	1.02	1.02	105	1.02	121
59 000	320	0.50	0.87	248	0.82	228
60 100	10	1.02	0.00	0	1.02	32
60 200	30	1.02	1.02	59	1.02	55
60 300	10	1.02	0.00	0	1.02	32
60 400	10	1.28	0.00	0	1.28	39
61 100	260	1.02	1.29	198	1.28	194
61 200	10	1.02	0.00	0	1.02	33
61 300	250	1.28	1.29	167	1.29	164
61 400	10	2.30	0.00	0	2.30	65

62 000	40	1.02	0.00	0	1.02	86
63 000	90	0.66	1.02	99	0.86	96
64 100	880	1.59	0.88	254	0.89	251
64 200	60	1.59	0.67	30	0.82	39
64 300	780	0.36	0.89	239	0.88	232
64 400	10	0.36	0.00	0	0.36	10
65 100	40	1.59	0.46	19	0.75	31
65 200	20	0.36	0.66	17	0.51	18
65 300	10	0.36	0.00	0	0.36	12
65 400	10	0.66	0.00	0	0.66	22
66 000	2120	1.02	0.93	719	0.93	711
67 000	80	0.66	1.02	82	0.84	85
68 000	40	1.02	0.00	0	1.02	64
69 000	40	1.02	0.00	0	1.02	82
70 000	80	0.66	1.02	79	0.84	89
71 000	160	0.66	0.78	139	0.75	146
72 100	20	1.02	1.02	32	1.02	44
72 200	80	1.02	1.02	74	1.02	73
72 300	10	1.02	0.00	0	1.02	35
72 400	50	1.02	1.02	91	1.02	74
73 100	220	2.30	1.20	151	1.25	156
73 200	110	2.30	1.21	94	1.31	104
73 300	20	1.59	1.02	29	1.31	45
73 400	90	2.30	1.18	73	1.31	81
74 100	10	0.36	0.00	0	0.36	14
74 200	10	1.02	0.00	0	1.02	32
74 300	10	1.02	0.00	0	1.02	34
74 400	10	1.02	0.00	0	1.02	32
75 000	40	1.02	0.00	0	1.02	90
76 000	770	0.36	0.91	361	0.89	353
77 000	40	1.02	0.00	0	1.02	82
78 000	1960	0.66	0.94	706	0.93	691
79 000	40	1.02	0.00	0	1.02	82
80 000	480	1.02	1.02	249	1.02	260
81 000	440	1.02	1.02	222	1.02	229
82 000	400	1.02	1.02	249	1.02	254
83 000	40	1.02	0.00	0	1.02	83
84 000	40	0.66	0.00	0	0.66	59
85 000	40	1.02	0.00	0	1.02	82
86 100	10	1.02	0.00	0	1.02	34
86 200	70	2.30	1.02	55	1.20	64
86 300	50	1.02	1.02	87	1.02	69
86 400	60	1.02	1.02	66	1.02	68
87 000	330	1.02	0.88	191	0.90	208
88 000	40	1.02	0.00	0	1.02	86
89 000	690	0.80	0.91	336	0.91	335
90 000	40	1.02	0.00	0	1.02	89
91 000	1840	1.02	0.93	705	0.93	702
92 000	1080	1.02	0.97	502	0.98	500
93 000	1000	1.02	0.97	439	0.97	443
94 000	80	1.02	1.02	78	1.02	93
95 000	40	1.02	0.00	0	1.02	85
96 000	320	1.02	1.02	183	1.02	188
97 000	40	1.02	0.00	0	1.02	74
98 000	240	1.02	0.82	143	0.85	163
99 000	280	1.02	0.85	167	0.88	185
100 000	570	1.02	0.89	291	0.90	292
101 000	610	1.02	0.90	340	0.91	351
102 000	240	1.02	0.88	144	0.90	160
103 000	680	1.02	0.85	312	0.86	316
104 000	40	1.02	0.00	0	1.02	86
105 000	360	1.02	0.87	181	0.88	186
106 000	40	1.02	0.00	0	1.02	86
107 000	40	1.02	0.00	0	1.02	87
108 000	280	1.02	1.02	217	1.02	221
109 000	80	1.02	1.02	80	1.02	96
110 000	40	1.02	0.00	0	1.02	86
111 000	200	1.02	0.77	125	0.82	140
112 000	80	0.66	0.66	54	0.66	72
113 000	200	1.02	0.84	170	0.88	181
114 000	40	1.02	0.00	0	1.02	86
115 000	200	1.02	0.84	143	0.88	155
116 000	360	0.66	0.85	180	0.83	184
117 000	40	0.66	0.00	0	0.66	58
118 000	320	0.80	0.88	229	0.87	226
119 000	40	1.02	0.00	0	1.02	89
120 000	80	1.02	1.02	88	1.02	118
121 000	120	1.02	1.02	112	1.02	129
122 000	160	1.02	1.02	135	1.02	157
123 000	40	1.02	0.00	0	1.02	86
124 000	160	0.36	0.90	117	0.77	104
125 000	40	0.66	0.00	0	0.66	52
126 000	40	1.02	0.00	0	1.02	83
127 000	80	1.02	1.02	85	1.02	114
128 000	160	0.66	0.90	132	0.84	135
129 000	320	0.36	0.92	193	0.85	188
130 000	40	0.36	0.00	0	0.36	37
131 000	160	0.66	0.80	107	0.77	110
132 000	80	1.02	1.02	88	1.02	105
133 000	40	1.02	0.00	0	1.02	83
134 000	80	0.66	1.02	81	0.84	92
135 000	40	1.02	0.00	0	1.02	73
136 000	40	1.02	0.00	0	1.02	83
137 000	40	0.66	0.00	0	0.66	55
138 000	280	0.66	0.96	199	0.92	206
139 000	240	0.66	1.02	188	0.96	195
140 000	80	1.02	1.02	85	1.02	105
141 000	40	1.02	0.00	0	1.02	89
142 000	200	1.02	1.02	169	1.02	180
143 000	40	1.02	0.00	0	1.02	90
144 000	40	1.02	0.00	0	1.02	83
145 000	160	1.02	1.02	167	1.02	172
146 000	40	1.02	0.00	0	1.02	78
147 000	80	1.02	1.02	88	1.02	118

Condensed Soil Loss

Cell Num	Div	Drainage Area (acres)	RUNOFF Volume (in.)	Generated Above (%)	Peak Rate (cfs)	Cell Erosion (t/a)	SEDIMENT Generated Above (tons)	Within (tons)	Yield (tons)	Depo (%)
1	000	40	1.02	0.0	82	0.58	0.00	23.24	13.95	40
2	000	40	1.02	0.0	78	0.36	0.00	14.32	8.53	40
3	000	80	0.66	60.7	78	0.12	13.95	4.80	9.61	49
4	000	80	0.85	54.5	86	0.11	8.53	4.28	6.79	47
5	000	40	1.02	0.0	83	0.68	0.00	27.15	16.33	40
6	000	40	1.02	0.0	89	0.90	0.00	35.93	21.99	39
7	000	40	1.02	0.0	87	0.78	0.00	31.09	18.91	39
8	000	40	1.02	0.0	82	0.65	0.00	26.09	15.65	40
9	000	40	1.02	0.0	69	0.09	0.00	3.57	2.20	38
10	000	40	1.02	0.0	87	0.96	0.00	38.41	23.33	39

11 000	120	1.02	62.2	112	0.31	9.61	12.24	14.35	34
12 000	440	0.00	0.0	0	0.06	52.26	2.32	0.00	100
13 000	80	0.00	0.0	0	0.25	16.33	9.81	0.00	100
14 000	40	1.02	0.0	88	0.36	0.00	14.41	8.86	39
15 000	120	1.02	66.7	136	0.58	40.90	23.14	35.03	45
16 000	80	1.02	50.0	114	0.78	15.65	31.12	28.65	39
17 000	120	1.02	66.7	130	0.70	28.65	28.17	34.32	40
18 100	130	1.02	92.3	122	0.51	34.32	5.05	26.56	33
18 200	5360	2.30	99.6	1240	0.00	92.20	0.00	65.02	29
18 300	10	1.02	0.0	33	1.01	0.00	10.06	6.23	38
18 400	5180	2.30	99.6	914	0.00	75.50	0.00	63.45	16
19 000	80	1.02	50.0	93	0.16	23.33	6.32	14.56	51
20 000	200	0.66	85.1	172	0.30	29.59	11.93	31.12	25
21 000	40	1.02	0.0	87	0.83	0.00	33.14	20.12	39
22 000	160	1.02	75.0	189	0.56	52.03	22.28	48.73	34
23 000	40	1.02	0.0	89	0.94	0.00	37.73	23.06	39
24 000	160	1.02	75.0	160	0.69	35.03	27.73	42.81	32
25 000	40	1.02	0.0	87	0.50	0.00	20.01	12.22	39
26 000	80	1.02	50.0	111	0.66	12.22	26.44	24.07	38
27 000	120	1.02	66.7	121	0.61	24.07	24.51	29.17	40
28 100	10	1.02	0.0	33	0.48	0.00	4.80	3.01	37
28 200	5160	2.30	99.6	926	0.00	80.07	0.00	69.28	13
28 300	130	1.02	92.3	115	0.27	29.17	2.69	21.55	32
28 400	5140	2.30	99.6	939	0.00	95.78	0.00	77.07	20
29 100	10	2.30	0.0	63	0.00	0.00	0.00	0.11	-100
29 200	20	0.71	50.0	32	0.29	2.09	2.94	3.10	38
29 300	4980	2.30	99.5	1333	0.00	79.08	0.00	73.76	7
29 400	30	2.30	38.1	42	0.00	3.10	0.00	0.36	88
30 100	10	0.71	0.0	23	0.35	0.00	3.48	2.09	40
30 200	10	0.71	0.0	25	0.75	0.00	7.53	4.55	40
30 300	10	2.30	0.0	52	0.00	0.00	0.00	0.03	-100
30 400	20	0.71	50.0	25	0.17	4.55	1.67	2.89	54
31 000	40	1.02	0.0	80	0.20	0.00	8.08	4.90	39
32 000	40	1.02	0.0	84	0.68	0.00	27.03	16.32	40
33 000	80	0.71	59.1	93	0.21	16.32	8.23	15.04	39
34 000	80	1.02	50.0	117	0.82	15.68	32.70	29.84	38
35 000	280	1.02	85.7	260	0.58	78.57	23.40	74.48	27
36 000	40	1.02	0.0	90	0.43	0.00	17.28	10.67	38
37 000	200	1.02	80.0	174	1.01	42.81	40.31	60.75	27
38 100	210	1.02	95.2	165	0.42	60.75	4.19	51.70	20
38 200	10	1.02	0.0	33	0.69	0.00	6.88	1.89	73
38 300	220	1.02	95.5	166	0.91	51.70	9.15	50.29	17
38 400	240	1.28	94.8	157	0.00	52.18	0.00	8.31	84
39 100	10	1.02	0.0	33	0.48	0.00	4.84	3.02	38
39 200	10	0.36	0.0	15	0.91	0.00	9.12	5.25	42
39 300	20	1.02	50.0	36	0.00	3.02	0.00	0.23	92
39 400	20	1.02	26.2	20	0.00	5.25	0.00	0.26	95
40 100	10	1.02	0.0	34	0.42	0.00	4.16	2.62	37
40 200	10	1.02	0.0	25	0.01	0.00	0.10	0.11	-16
40 300	20	0.66	60.7	32	0.09	2.62	0.93	2.03	43
40 400	20	0.36	73.8	26	0.00	0.11	0.00	0.05	60
41 100	10	0.36	0.0	12	0.00	0.00	0.00	0.04	-100
41 200	20	1.59	18.6	30	0.00	0.04	0.03	0.48	-84
41 300	10	0.66	0.0	23	0.24	0.00	2.36	1.44	39
41 400	20	1.02	39.3	27	0.01	1.44	0.09	0.78	49
42 000	4930	2.30	98.1	924	0.00	85.12	0.00	78.62	8
43 100	130	2.30	84.6	104	0.00	7.97	0.00	1.32	83
43 200	90	0.75	91.6	84	0.01	8.24	0.12	5.05	40
43 300	2210	2.30	98.9	636	0.00	54.39	0.00	49.60	9
43 400	10	0.66	0.0	17	0.00	0.00	0.03	0.08	-64
44 000	80	1.02	50.0	78	0.26	4.90	10.40	8.24	46
45 000	40	1.02	0.0	85	0.65	0.00	25.93	15.68	40
46 000	320	1.02	87.5	277	1.01	74.48	40.38	89.11	22
47 000	400	1.02	90.0	290	0.14	99.78	5.56	84.18	20
48 000	760	1.02	94.3	417	0.10	125.46	3.91	111.03	14
49 100	780	1.02	98.6	360	0.17	104.42	1.73	97.09	9
49 200	1070	1.02	99.0	435	0.08	107.18	0.76	94.53	12
49 300	770	1.02	98.6	444	0.80	111.03	7.97	104.42	12
49 400	40	1.02	75.0	48	0.03	2.23	0.26	1.78	28
50 100	1370	2.30	98.4	383	0.00	101.41	0.00	28.77	72
50 200	1420	2.30	98.4	383	0.00	30.35	0.00	24.77	18
50 300	270	1.02	97.0	188	0.21	6.83	2.07	6.65	25
50 400	20	1.02	50.0	40	0.16	0.79	1.59	1.32	45
51 100	1460	2.30	98.5	492	0.00	30.68	0.00	22.02	28
51 200	1500	0.36	99.8	594	0.06	30.24	0.62	35.77	-14
51 300	10	1.02	0.0	34	0.62	0.00	6.19	3.88	37
51 400	10	1.02	0.0	35	1.31	0.00	13.06	8.17	37
52 100	1510	1.02	99.3	629	0.58	35.77	5.78	35.74	14
52 200	1530	1.59	99.0	404	0.00	36.82	0.00	20.58	44
52 300	10	1.02	0.0	29	0.16	0.00	1.62	1.08	33
52 400	10	1.02	0.0	31	0.18	0.00	1.83	1.24	33
53 000	2530	2.30	96.4	536	0.00	38.02	0.00	33.42	12
54 100	2190	2.30	98.9	494	0.00	57.72	0.00	54.31	6
54 200	2180	0.66	99.7	643	0.00	62.64	0.00	57.72	8
54 300	10	1.02	0.0	26	0.00	0.00	0.03	0.10	-68
54 400	2170	0.66	99.7	453	0.00	249.65	0.00	62.64	75
55 000	2160	1.02	98.0	800	0.64	250.24	25.48	249.65	9
56 000	40	1.02	0.0	87	0.91	0.00	36.30	22.05	39
57 000	80	1.02	50.0	107	0.45	11.85	18.06	18.06	40
58 000	120	1.02	66.7	121	0.41	18.06	16.51	20.37	41
59 000	320	0.50	92.4	228	0.03	53.86	1.34	41.28	25
60 100	10	1.02	0.0	32	0.55	0.00	5.49	1.51	73
60 200	30	1.02	66.7	55	0.37	2.79	3.68	2.23	66
60 300	10	1.02	0.0	32	0.47	0.00	4.67	1.28	73
60 400	10	1.28	0.0	39	0.47	0.00	4.73	1.36	71
61 100	260	1.02	96.9	194	0.19	2.37	1.89	6.83	-38
61 200	10	1.02	0.0	33	0.27	0.00	2.73	0.79	71
61 300	250	1.28	96.0	164	0.00	5.62	0.00	2.37	58
61 400	10	2.30	0.0	65	0.54	0.00	5.37	1.76	67
62 000	40	1.02	0.0	86	0.34	0.00	13.56	8.29	39
63 000	90	0.66	65.9	96	0.13	12.30	5.18	10.09	42
64 100	880	1.59	98.0	251	0.00	93.30	0.00	15.81	83
64 200	60	1.59	67.7	39	0.00	0.31	0.00	0.30	5
64 300	780	0.36	99.5	232	0.00	102.45	0.01	83.21	19
64 400	10	0.36	0.0	10	0.00	0.00	0.04	0.11	-65
65 100	40	1.59	46.6	31	0.00	1.27	0.00	0.20	84
65 200	20	0.36	64.5	18	0.00	0.43	0.02	0.34	23
65 300	10	0.36	0.0	12	0.17	0.00	1.68	0.93	45
65 400	10	0.66	0.0	22	0.16	0.00	1.63	0.43	74
66 000	2120	1.02	97.9	711	0.12	275.49	4.90	250.24	11
67 000	80	0.66	60.7	85	0.49	2.01	19.43	11.50	46
68 000	40	1.02	0.0	64	0.08	0.00	3.33	2.01	40
69 000	40	1.02	0.0	82	0.49	0.00	19.70	11.85	40
70 000	80	0.66	60.7	89	0.17	14.36	6.99	13.02	39
71 000	160	0.66	78.0	146	0.65	22.82	26.02	33.49	31
72 100	20	1.02	50.0	44	0.58	2.65	5.85	4.80	43
72 200	80	1.02	87.5	73	0.03	11.97	0.28	7.67	37
72 300	10	1.02	0.0	35	0.94	0.00	9.42	2.65	72
72 400	50	1.02	80.0	74	1.00	4.04	9.99	7.17	49
73 100	220	2.30	91.6	156	0.00	12.15	0.00	2.50	79

73	200	110	2.30	84.0	104	0.00	1.14	0.00	0.83	27
73	300	20	1.59	39.1	45	0.07	6.30	0.74	3.65	48
73	400	90	2.30	80.4	81	0.00	2.97	0.00	0.94	68
74	100	10	0.36	0.0	14	0.08	0.00	0.77	0.20	74
74	200	10	1.02	0.0	32	0.58	0.00	5.77	4.01	31
74	300	10	1.02	0.0	34	0.31	0.00	3.08	1.96	37
74	400	10	1.02	0.0	32	0.86	0.00	8.59	5.29	38
75	000	40	1.02	0.0	90	0.90	0.00	36.05	22.14	39
76	000	770	0.36	97.9	353	0.04	120.42	1.52	102.45	16
77	000	40	1.02	0.0	82	0.53	0.00	21.15	12.71	40
78	000	1960	0.66	98.6	691	0.19	262.43	7.40	241.94	10
79	000	40	1.02	0.0	82	0.56	0.00	22.30	13.39	40
80	000	480	1.02	91.7	260	0.34	65.36	13.66	66.85	15
81	000	440	1.02	90.9	229	0.23	73.30	9.07	65.36	21
82	000	400	1.02	90.0	254	0.62	72.06	24.90	73.30	24
83	000	40	1.02	0.0	83	0.60	0.00	23.85	14.36	40
84	000	40	0.66	0.0	59	0.42	0.00	16.82	9.80	42
85	000	40	1.02	0.0	82	0.39	0.00	15.54	4.04	74
86	100	10	1.02	0.0	34	1.01	0.00	10.14	6.30	38
86	200	70	2.30	72.7	64	0.00	9.13	0.00	1.02	89
86	300	50	1.02	80.0	69	1.12	4.22	11.20	8.05	48
86	400	60	1.02	83.3	68	0.66	8.05	6.60	9.13	38
87	000	330	1.02	86.2	208	0.62	41.71	24.83	50.11	25
88	000	40	1.02	0.0	86	0.23	0.00	9.11	5.62	38
89	000	690	0.80	94.9	335	0.20	116.02	7.83	98.29	21
90	000	40	1.02	0.0	89	0.98	0.00	39.26	23.99	39
91	000	1840	1.02	97.6	702	0.17	249.96	6.94	236.32	8
92	000	1080	1.02	96.1	500	0.49	151.32	19.44	147.74	13
93	000	1000	1.02	95.8	443	0.23	151.98	9.01	142.91	11
94	000	80	1.02	50.0	93	0.29	13.68	11.69	12.73	50
95	000	40	1.02	0.0	85	0.57	0.00	22.79	13.80	39
96	000	320	1.02	87.5	188	0.23	70.87	9.05	58.25	27
97	000	40	1.02	0.0	74	0.18	0.00	7.05	4.22	40
98	000	240	1.02	80.0	163	0.57	15.22	22.68	26.86	29
99	000	280	1.02	83.3	185	0.58	26.86	23.03	36.42	27
100	000	570	1.02	92.0	292	0.26	83.41	10.52	71.75	24
101	000	610	1.02	92.6	351	1.70	71.75	68.15	110.40	21
102	000	240	1.02	81.1	160	0.12	25.45	4.81	23.07	24
103	000	680	1.02	93.0	316	0.23	87.15	9.17	78.24	19
104	000	40	1.02	0.0	86	0.34	0.00	13.76	8.41	39
105	000	360	1.02	87.2	186	0.03	77.78	1.20	57.09	28
106	000	40	1.02	0.0	86	0.63	0.00	25.24	15.32	39
107	000	40	1.02	0.0	87	0.56	0.00	22.43	13.68	39
108	000	280	1.02	85.7	221	0.55	73.88	22.04	70.87	26
109	000	80	1.02	50.0	96	0.46	23.86	18.55	22.29	47
110	000	40	1.02	0.0	86	0.64	0.00	25.49	15.46	39
111	000	200	1.02	75.0	140	0.21	13.58	8.57	15.22	31
112	000	80	0.66	50.0	72	0.17	1.09	6.83	4.47	44
113	000	200	1.02	76.7	181	0.56	26.62	22.35	33.31	32
114	000	40	1.02	0.0	86	0.64	0.00	25.75	15.62	39
115	000	200	1.02	76.7	155	0.26	27.48	10.21	25.45	32
116	000	360	0.66	91.1	184	0.28	63.52	11.32	56.79	24
117	000	40	0.66	0.0	58	0.31	0.00	12.50	7.29	42
118	000	320	0.80	88.4	226	0.45	87.66	18.17	77.78	27
119	000	40	1.02	0.0	89	0.90	0.00	35.82	21.93	39
120	000	80	1.02	50.0	118	0.84	12.39	33.79	31.15	33
121	000	120	1.02	66.7	129	0.56	31.15	22.27	32.79	39
122	000	160	1.02	75.0	157	0.93	32.79	37.27	51.59	26
123	000	40	1.02	0.0	86	0.87	0.00	34.83	23.86	32
124	000	160	0.36	88.2	104	0.00	22.04	0.16	13.58	39
125	000	40	0.66	0.0	52	0.11	0.00	4.42	1.09	75
126	000	40	1.02	0.0	83	0.27	0.00	10.71	6.53	39
127	000	80	1.02	50.0	114	0.76	13.90	30.31	27.03	39
128	000	160	0.66	80.3	135	0.16	33.08	6.41	27.48	30
129	000	320	0.36	94.7	188	0.07	81.12	2.62	63.52	24
130	000	40	0.36	0.0	37	0.59	0.00	23.72	13.15	45
131	000	160	0.66	78.4	110	0.15	40.48	6.04	28.39	39
132	000	80	1.02	50.0	105	0.90	26.29	36.19	37.34	40
133	000	40	1.02	0.0	83	0.51	0.00	20.53	12.39	40
134	000	80	0.66	60.7	92	0.34	4.37	13.55	6.58	63
135	000	40	1.02	0.0	73	0.17	0.00	6.92	4.37	37
136	000	40	1.02	0.0	83	0.58	0.00	23.07	13.90	40
137	000	40	0.66	0.0	55	0.26	0.00	10.51	6.06	42
138	000	280	0.66	89.7	206	0.78	73.90	31.08	81.12	23
139	000	240	0.66	88.5	195	0.71	68.18	28.58	73.90	24
140	000	80	1.02	50.0	105	0.43	31.94	17.24	27.33	44
141	000	40	1.02	0.0	89	0.95	0.00	38.06	26.29	31
142	000	200	1.02	80.0	180	0.91	64.25	36.43	68.18	32
143	000	40	1.02	0.0	90	1.30	0.00	52.11	31.94	39
144	000	40	1.02	0.0	83	0.69	0.00	27.68	16.65	40
145	000	160	1.02	75.0	172	1.10	51.28	44.18	64.25	33
146	000	40	1.02	0.0	78	0.40	0.00	16.06	9.55	41
147	000	80	1.02	50.0	118	1.18	9.55	47.38	34.62	39

Nutrient Analysis

N I T R O G E N

Cell Num	Div	Drainage Area (acres)	Sediment Within Cell (lbs/a)	Sediment Cell Outlet (lbs/a)	Water Soluble Within Cell (lbs/a)	Water Soluble Cell Outlet (lbs/a)	Conc (ppm)
1	000	40	2.05	1.36	4.14	4.14	18
2	000	40	1.39	0.92	4.14	4.14	18
3	000	80	0.58	0.58	1.20	2.67	14
4	000	80	0.53	0.44	0.87	2.50	12
5	000	40	2.32	1.55	4.14	4.14	18
6	000	40	2.90	1.96	4.14	4.14	18
7	000	40	2.59	1.74	4.14	4.14	18
8	000	40	2.25	1.49	4.14	4.14	18
9	000	40	0.46	0.31	4.14	4.14	18
10	000	40	3.06	2.06	4.14	4.14	18
11	000	120	1.23	0.58	2.68	2.67	13
12	000	440	0.32	0.00	0.35	0.00	0
13	000	80	1.03	0.00	1.83	0.00	0
14	000	40	1.40	0.95	1.21	1.21	5
15	000	120	2.04	1.18	4.14	4.14	18
16	000	80	2.59	1.39	4.35	4.25	18
17	000	120	2.39	1.16	4.14	4.21	18
18	100	130	1.83	0.89	4.14	4.21	18
18	200	5360	0.00	0.08	0.55	2.89	13
18	300	10	3.18	2.17	4.14	4.14	18
18	400	5180	0.00	0.11	0.42	2.85	13
19	000	80	0.72	0.81	2.68	3.41	15
20	000	200	1.20	0.71	1.20	2.70	13
21	000	40	2.72	1.83	4.14	4.14	18
22	000	160	1.98	1.22	4.14	3.41	15
23	000	40	3.02	2.04	4.14	4.14	18
24	000	160	2.36	1.10	2.68	3.78	16
25	000	40	1.82	1.22	2.68	2.68	12
26	000	80	2.61	1.39	2.53	2.60	11

27 000	120	2.14	1.02	4.14	3.12	13
28 100	10	1.76	1.21	2.68	2.68	12
28 200	5160	0.00	0.12	0.42	2.85	13
28 300	130	1.11	0.75	2.68	3.08	13
28 400	5140	0.00	0.13	0.42	2.86	13
29 100	10	0.00	0.07	0.55	0.55	1
29 200	20	1.19	0.71	0.94	1.14	7
29 300	4980	0.00	0.13	0.42	2.87	13
29 400	30	0.00	0.11	0.42	0.90	3
30 100	10	1.36	0.90	1.34	1.34	8
30 200	10	2.52	1.69	1.34	1.34	8
30 300	10	0.00	0.03	0.55	0.55	1
30 400	20	0.75	0.67	1.34	1.34	8
31 000	40	0.88	0.59	2.68	2.68	12
32 000	40	2.31	1.54	4.14	4.14	18
33 000	80	0.89	0.83	1.34	2.74	14
34 000	80	2.69	1.44	4.14	4.14	18
35 000	280	2.06	1.10	4.14	3.72	16
36 000	40	1.62	1.10	1.86	1.86	8
37 000	200	3.18	1.22	4.14	3.85	17
38 100	210	1.58	1.03	2.68	3.79	16
38 200	10	1.99	0.71	3.30	3.30	14
38 300	220	3.39	1.12	3.91	3.80	16
38 400	240	0.00	0.18	0.26	3.63	16
39 100	10	1.77	1.22	2.68	2.68	12
39 200	10	2.94	1.89	0.49	0.49	6
39 300	20	0.00	0.08	0.21	1.44	6
39 400	20	0.00	0.08	0.21	0.35	2
40 100	10	1.57	1.08	2.68	2.68	12
40 200	10	0.06	0.07	2.15	2.15	9
40 300	20	0.47	0.51	0.84	1.76	9
40 400	20	0.00	0.02	0.07	1.11	7
41 100	10	0.00	0.04	0.07	0.07	1
41 200	20	0.03	0.14	0.33	0.20	1
41 300	10	1.00	0.67	0.84	0.84	6
41 400	20	0.07	0.24	0.21	0.53	3
42 000	4930	0.00	0.13	0.42	2.89	13
43 100	130	0.00	0.07	0.55	2.40	9
43 200	90	0.09	0.32	0.16	3.05	14
43 300	2210	0.00	0.17	0.42	2.99	14
43 400	10	0.03	0.06	0.13	0.13	1
44 000	80	1.08	0.51	4.14	3.41	15
45 000	40	2.24	1.50	4.14	4.14	18
46 000	320	3.19	1.14	4.14	3.78	16
47 000	400	0.65	0.91	1.21	3.33	14
48 000	760	0.49	0.68	2.68	2.96	14
49 100	780	0.78	0.60	4.14	2.99	14
49 200	1070	0.34	0.39	3.30	3.16	14
49 300	770	2.64	0.64	4.14	2.98	14
49 400	40	0.17	0.26	4.14	3.51	15
50 100	1370	0.00	0.12	0.55	3.39	14
50 200	1420	0.00	0.14	0.42	3.31	14
50 300	270	0.90	0.16	2.68	4.54	16
50 400	20	0.73	0.36	2.68	2.41	10
51 100	1460	0.00	0.11	0.56	3.27	14
51 200	1500	0.29	0.14	0.25	3.23	14
51 300	10	2.16	1.48	4.14	4.14	18
51 400	10	3.92	2.69	4.14	4.14	18
52 100	1510	2.04	0.16	4.14	3.24	14
52 200	1530	0.00	0.09	0.33	3.22	14
52 300	10	0.74	0.53	4.14	4.14	18
52 400	10	0.81	0.59	2.68	2.68	12
53 000	2530	0.00	0.11	0.42	2.88	13
54 100	2190	0.00	0.19	0.42	3.02	14
54 200	2180	0.00	0.20	0.42	3.03	14
54 300	10	0.03	0.07	0.21	0.21	1
54 400	2170	0.00	0.21	0.42	3.04	14
55 000	2160	2.21	0.56	4.14	3.05	14
56 000	40	2.93	1.97	4.14	4.14	18
57 000	80	1.67	0.96	4.14	4.14	18
58 000	120	1.56	0.77	4.14	4.14	18
59 000	320	0.18	0.52	0.10	2.54	14
60 100	10	1.66	0.59	3.30	3.30	14
60 200	30	1.21	0.34	3.30	3.30	14
60 300	10	1.46	0.52	3.30	3.30	14
60 400	10	1.48	0.55	5.92	5.92	20
61 100	260	0.83	0.17	2.68	4.61	16
61 200	10	0.95	0.35	2.15	2.15	9
61 300	250	0.00	0.06	0.26	4.69	16
61 400	10	1.64	0.67	45.41	45.41	87
62 000	40	1.33	0.90	2.71	2.71	12
63 000	90	0.62	0.55	0.14	1.70	9
64 100	880	0.00	0.11	0.33	2.60	13
64 200	60	0.00	0.05	0.42	0.38	2
64 300	780	0.02	0.53	0.07	2.73	14
64 400	10	0.04	0.09	0.07	0.07	1
65 100	40	0.00	0.04	0.33	0.45	3
65 200	20	0.02	0.10	0.07	0.48	4
65 300	10	0.76	0.47	0.50	0.50	6
65 400	10	0.63	0.22	0.89	0.89	6
66 000	2120	0.50	0.49	3.30	3.03	14
67 000	80	1.78	0.67	1.83	2.99	16
68 000	40	0.43	0.29	4.14	4.14	18
69 000	40	1.80	1.20	4.14	4.14	18
70 000	80	0.78	0.74	1.21	2.68	14
71 000	160	2.24	0.91	1.21	1.94	11
72 100	20	2.06	1.01	4.14	3.72	16
72 200	80	0.15	0.41	1.50	3.39	15
72 300	10	2.56	0.93	3.30	3.30	14
72 400	50	3.16	0.67	4.14	3.64	16
73 100	220	0.00	0.10	0.42	2.99	11
73 200	110	0.00	0.05	0.55	2.81	9
73 300	20	0.34	0.69	3.14	3.64	12
73 400	90	0.00	0.09	0.42	3.36	11
74 100	10	0.35	0.12	0.07	0.07	1
74 200	10	2.34	1.75	3.91	3.91	17
74 300	10	1.23	0.86	2.71	2.71	12
74 400	10	2.80	1.90	4.14	4.14	18
75 000	40	2.91	1.97	4.14	4.14	18
76 000	770	0.23	0.63	0.07	2.76	14
77 000	40	1.90	1.26	4.14	4.14	18
78 000	1960	0.82	0.59	1.83	3.01	14
79 000	40	1.98	1.32	4.14	4.14	18
80 000	480	1.34	0.65	4.14	3.32	14
81 000	440	0.97	0.69	4.14	3.25	14
82 000	400	2.17	0.81	2.68	3.16	14
83 000	40	2.09	1.39	4.14	4.14	18
84 000	40	1.58	1.03	1.20	1.20	8
85 000	40	1.26	0.43	3.51	3.51	15
86 100	10	3.20	2.19	4.14	4.14	18

86 200	70	0.00	0.09	0.55	3.88	14
86 300	50	3.46	0.73	4.14	4.49	19
86 400	60	2.27	0.70	4.14	4.43	19
87 000	330	2.16	0.70	4.14	3.08	15
88 000	40	0.97	0.66	1.21	1.21	5
89 000	690	0.86	0.67	0.78	2.84	14
90 000	40	3.12	2.10	4.14	4.14	18
91 000	1840	0.78	0.61	4.14	2.98	14
92 000	1080	1.78	0.64	4.14	3.14	14
93 000	1000	0.96	0.67	4.14	3.11	14
94 000	80	1.18	0.73	4.14	3.41	15
95 000	40	2.02	1.35	2.68	2.68	12
96 000	320	0.96	0.81	2.68	3.28	14
97 000	40	0.79	0.52	4.57	4.58	20
98 000	240	2.01	0.55	4.14	2.68	14
99 000	280	2.03	0.62	4.14	2.89	15
100 000	570	1.09	0.60	4.14	3.01	15
101 000	610	4.85	0.81	4.14	3.08	15
102 000	240	0.58	0.49	2.71	2.68	13
103 000	680	0.97	0.56	2.71	2.60	13
104 000	40	1.35	0.91	2.71	2.71	12
105 000	360	0.19	0.73	2.68	2.71	14
106 000	40	2.19	1.47	2.68	2.68	12
107 000	40	1.99	1.34	2.68	2.68	12
108 000	280	1.96	1.05	2.68	3.36	15
109 000	80	1.71	1.14	4.14	4.03	17
110 000	40	2.21	1.48	4.14	4.14	18
111 000	200	0.92	0.40	2.68	2.38	13
112 000	80	0.77	0.31	1.20	1.04	7
113 000	200	1.99	0.75	4.42	2.66	13
114 000	40	2.22	1.49	4.14	4.14	18
115 000	200	1.06	0.61	2.71	2.68	13
116 000	360	1.15	0.72	1.21	2.69	14
117 000	40	1.25	0.81	1.21	1.21	8
118 000	320	1.68	1.02	1.70	2.71	14
119 000	40	2.90	1.96	2.68	2.68	12
120 000	80	3.18	1.71	2.74	2.71	12
121 000	120	1.98	1.12	2.77	2.73	12
122 000	160	3.44	1.47	4.62	3.20	14
123 000	40	3.26	2.41	3.91	3.91	17
124 000	160	0.04	0.44	0.07	2.31	13
125 000	40	0.46	0.15	0.88	0.88	6
126 000	40	1.10	0.74	2.68	2.68	12
127 000	80	2.53	1.33	4.14	4.14	18
128 000	160	0.73	0.77	1.20	2.67	14
129 000	320	0.36	0.87	0.07	2.87	15
130 000	40	2.08	1.30	0.49	0.49	6
131 000	160	0.70	0.79	1.20	2.13	12
132 000	80	3.36	1.98	4.41	4.41	19
133 000	40	1.86	1.24	2.68	2.68	12
134 000	80	1.13	0.36	0.88	2.51	13
135 000	40	0.78	0.54	4.14	4.14	18
136 000	40	2.04	1.36	4.14	4.14	18
137 000	40	1.09	0.70	1.20	1.20	8
138 000	280	2.59	1.17	1.20	3.27	16
139 000	240	2.42	1.23	1.20	3.61	17
140 000	80	1.61	1.34	2.68	3.41	15
141 000	40	3.50	2.60	4.41	4.41	19
142 000	200	2.94	1.34	4.14	4.10	18
143 000	40	3.91	2.64	4.14	4.14	18
144 000	40	2.36	1.57	4.14	4.14	18
145 000	160	3.94	1.75	3.91	4.08	18
146 000	40	1.52	1.01	4.14	4.14	18
147 000	80	3.62	1.62	4.14	4.14	18

Nutrient Analysis
P H O S P H O R U S

		Sediment		Water Soluble		
Cell Num Div	Drainage Area (acres)	Within Cell (lbs/a)	Cell Outlet (lbs/a)	Within Cell (lbs/a)	Cell Outlet (lbs/a)	Conc (ppm)
1 000	40	1.02	0.68	0.85	0.85	4
2 000	40	0.70	0.46	0.85	0.85	4
3 000	80	0.29	0.29	0.23	0.54	3
4 000	80	0.26	0.22	0.16	0.50	2
5 000	40	1.16	0.77	0.85	0.85	4
6 000	40	1.45	0.98	0.85	0.85	4
7 000	40	1.29	0.87	0.85	0.85	4
8 000	40	1.12	0.75	0.85	0.85	4
9 000	40	0.23	0.16	0.85	0.85	4
10 000	40	1.53	1.03	0.85	0.85	4
11 000	120	0.61	0.29	0.54	0.54	3
12 000	440	0.16	0.00	0.06	0.00	0
13 000	80	0.51	0.00	0.36	0.00	0
14 000	40	0.70	0.47	0.22	0.22	1
15 000	120	1.02	0.59	0.85	0.85	4
16 000	80	1.29	0.70	0.90	0.87	4
17 000	120	1.19	0.58	0.85	0.86	4
18 100	130	0.92	0.44	0.85	0.86	4
18 200	5360	0.00	0.04	0.03	0.59	3
18 300	10	1.59	1.08	0.85	0.85	4
18 400	5180	0.00	0.05	0.76	0.59	3
19 000	80	0.36	0.40	0.54	0.69	3
20 000	200	0.60	0.36	0.23	0.54	3
21 000	40	1.36	0.91	0.85	0.85	4
22 000	160	0.99	0.61	0.85	0.69	3
23 000	40	1.51	1.02	0.85	0.85	4
24 000	160	1.18	0.55	0.54	0.77	3
25 000	40	0.91	0.61	0.54	0.54	2
26 000	80	1.31	0.70	0.51	0.52	2
27 000	120	1.07	0.51	0.85	0.63	3
28 100	10	0.88	0.60	0.54	0.54	2
28 200	5160	0.00	0.06	0.48	0.59	3
28 300	130	0.55	0.38	0.54	0.62	3
28 400	5140	0.00	0.06	0.48	0.59	3
29 100	10	0.00	0.04	0.03	0.03	0
29 200	20	0.59	0.36	0.17	0.22	1
29 300	4980	0.00	0.06	0.16	0.59	3
29 400	30	0.00	0.05	0.14	0.19	1
30 100	10	0.68	0.45	0.26	0.26	2
30 200	10	1.26	0.84	0.26	0.26	2
30 300	10	0.00	0.01	0.03	0.03	0
30 400	20	0.38	0.34	0.26	0.26	2
31 000	40	0.44	0.29	0.54	0.54	2
32 000	40	1.16	0.77	0.85	0.85	4
33 000	80	0.45	0.42	0.26	0.55	3
34 000	80	1.35	0.72	0.85	0.85	4
35 000	280	1.03	0.55	0.85	0.76	3
36 000	40	0.81	0.55	0.36	0.36	2

37 000	200	1.59	0.61	0.85	0.78	3
38 100	210	0.79	0.52	0.54	0.77	3
38 200	10	1.00	0.35	0.68	0.68	3
38 300	220	1.69	0.56	0.80	0.77	3
38 400	240	0.00	0.09	0.01	0.74	3
39 100	10	0.89	0.61	0.54	0.54	2
39 200	10	1.47	0.95	0.09	0.09	1
39 300	20	0.00	0.04	0.01	0.27	1
39 400	20	0.00	0.04	0.01	0.05	0
40 100	10	0.78	0.54	0.54	0.54	2
40 200	10	0.03	0.04	0.43	0.43	2
40 300	20	0.24	0.25	0.16	0.35	2
40 400	20	0.00	0.01	0.00	0.22	1
41 100	10	0.00	0.02	0.00	0.00	0
41 200	20	0.01	0.07	0.02	0.01	0
41 300	10	0.50	0.33	0.16	0.16	1
41 400	20	0.04	0.12	0.01	0.08	0
42 000	4930	0.00	0.07	0.01	0.59	3
43 100	130	0.00	0.03	0.03	0.47	2
43 200	90	0.05	0.16	0.01	0.62	3
43 300	2210	0.00	0.09	0.01	0.61	3
43 400	10	0.01	0.03	0.01	0.01	0
44 000	80	0.54	0.26	0.85	0.69	3
45 000	40	1.12	0.75	0.85	0.85	4
46 000	320	1.59	0.57	0.85	0.77	3
47 000	400	0.33	0.45	0.22	0.67	3
48 000	760	0.25	0.34	0.54	0.60	3
49 100	780	0.39	0.30	0.85	0.60	3
49 200	1070	0.17	0.19	0.68	0.64	3
49 300	770	1.32	0.32	0.85	0.60	3
49 400	40	0.08	0.13	0.85	0.72	3
50 100	1370	0.00	0.06	0.03	0.70	3
50 200	1420	0.00	0.07	0.02	0.69	3
50 300	270	0.45	0.08	0.54	1.02	4
50 400	20	0.36	0.18	0.54	0.48	2
51 100	1460	0.00	0.06	0.03	0.68	3
51 200	1500	0.15	0.07	0.04	0.67	3
51 300	10	1.08	0.74	0.85	0.85	4
51 400	10	1.96	1.35	0.85	0.85	4
52 100	1510	1.02	0.08	0.85	0.67	3
52 200	1530	0.00	0.04	0.02	0.67	3
52 300	10	0.37	0.27	0.85	0.85	4
52 400	10	0.41	0.30	0.54	0.54	2
53 000	2530	0.00	0.06	0.48	0.60	3
54 100	2190	0.00	0.09	0.43	0.61	3
54 200	2180	0.00	0.10	0.38	0.61	3
54 300	10	0.01	0.03	0.01	0.01	0
54 400	2170	0.00	0.11	0.01	0.62	3
55 000	2160	1.10	0.28	0.85	0.62	3
56 000	40	1.46	0.98	0.85	0.85	4
57 000	80	0.84	0.48	0.85	0.85	4
58 000	120	0.78	0.38	0.85	0.85	4
59 000	320	0.09	0.26	0.01	0.51	3
60 100	10	0.83	0.30	0.68	0.68	3
60 200	30	0.60	0.17	0.68	0.68	3
60 300	10	0.73	0.26	0.68	0.68	3
60 400	10	0.74	0.27	1.26	1.26	4
61 100	260	0.42	0.09	0.54	1.04	4
61 200	10	0.48	0.18	0.43	0.43	2
61 300	250	0.00	0.03	0.01	1.06	4

61 400	10	0.82	0.33	10.63	10.63	20
62 000	40	0.67	0.45	0.54	0.54	2
63 000	90	0.31	0.27	0.01	0.33	2
64 100	880	0.00	0.05	0.02	0.52	3
64 200	60	0.00	0.03	0.02	0.05	0
64 300	780	0.01	0.26	0.00	0.55	3
64 400	10	0.02	0.04	0.00	0.00	0
65 100	40	0.00	0.02	0.02	0.07	0
65 200	20	0.01	0.05	0.00	0.09	1
65 300	10	0.38	0.24	0.09	0.09	1
65 400	10	0.31	0.11	0.17	0.17	1
66 000	2120	0.25	0.24	0.68	0.61	3
67 000	80	0.89	0.34	0.36	0.60	3
68 000	40	0.22	0.14	0.85	0.85	4
69 000	40	0.90	0.60	0.85	0.85	4
70 000	80	0.39	0.37	0.23	0.54	3
71 000	160	1.12	0.45	0.23	0.38	2
72 100	20	1.03	0.51	0.85	0.76	3
72 200	80	0.08	0.21	0.29	0.70	3
72 300	10	1.28	0.46	0.68	0.68	3
72 400	50	1.58	0.33	0.85	0.75	3
73 100	220	0.00	0.05	0.76	0.66	2
73 200	110	0.00	0.03	0.03	0.60	2
73 300	20	0.17	0.34	0.65	0.75	3
73 400	90	0.00	0.05	0.58	0.73	2
74 100	10	0.17	0.06	0.00	0.00	0
74 200	10	1.17	0.88	0.80	0.80	3
74 300	10	0.62	0.43	0.54	0.54	2
74 400	10	1.40	0.95	0.85	0.85	4
75 000	40	1.46	0.99	0.85	0.85	4
76 000	770	0.12	0.32	0.00	0.56	3
77 000	40	0.95	0.63	0.85	0.85	4
78 000	1960	0.41	0.30	0.36	0.61	3
79 000	40	0.99	0.66	0.85	0.85	4
80 000	480	0.67	0.33	0.85	0.67	3
81 000	440	0.48	0.34	0.85	0.66	3
82 000	400	1.08	0.41	0.54	0.64	3
83 000	40	1.05	0.70	0.85	0.85	4
84 000	40	0.79	0.51	0.23	0.23	2
85 000	40	0.63	0.21	0.73	0.73	3
86 100	10	1.60	1.09	0.85	0.85	4
86 200	70	0.00	0.05	0.03	0.78	3
86 300	50	1.73	0.37	0.85	0.92	4
86 400	60	1.13	0.35	0.85	0.91	4
87 000	330	1.08	0.35	0.85	0.62	3
88 000	40	0.48	0.33	0.22	0.22	1
89 000	690	0.43	0.33	0.14	0.57	3
90 000	40	1.56	1.05	0.85	0.85	4
91 000	1840	0.39	0.31	0.85	0.60	3
92 000	1080	0.89	0.32	0.85	0.64	3
93 000	1000	0.48	0.33	0.85	0.63	3
94 000	80	0.59	0.36	0.85	0.69	3
95 000	40	1.01	0.68	0.54	0.54	2
96 000	320	0.48	0.40	0.54	0.67	3
97 000	40	0.39	0.26	0.94	0.94	4
98 000	240	1.00	0.27	0.85	0.54	3
99 000	280	1.02	0.31	0.85	0.58	3
100 000	570	0.54	0.30	0.85	0.61	3
101 000	610	2.42	0.40	0.85	0.63	3
102 000	240	0.29	0.24	0.54	0.54	3

103 000	680	0.49	0.28	0.54	0.52	3
104 000	40	0.67	0.45	0.54	0.54	2
105 000	360	0.10	0.36	0.54	0.55	3
106 000	40	1.09	0.73	0.54	0.54	2
107 000	40	1.00	0.67	0.54	0.54	2
108 000	280	0.98	0.53	0.54	0.69	3
109 000	80	0.86	0.57	0.85	0.82	4
110 000	40	1.10	0.74	0.85	0.85	4
111 000	200	0.46	0.20	0.54	0.48	3
112 000	80	0.38	0.16	0.23	0.20	1
113 000	200	0.99	0.38	0.93	0.54	3
114 000	40	1.11	0.75	0.85	0.85	4
115 000	200	0.53	0.30	0.54	0.54	3
116 000	360	0.58	0.36	0.23	0.54	3
117 000	40	0.62	0.41	0.23	0.23	2
118 000	320	0.84	0.51	0.33	0.55	3
119 000	40	1.45	0.98	0.54	0.54	2
120 000	80	1.59	0.86	0.56	0.55	2
121 000	120	0.99	0.56	0.57	0.55	2
122 000	160	1.72	0.74	0.96	0.65	3
123 000	40	1.63	1.20	0.80	0.80	3
124 000	160	0.02	0.22	0.00	0.47	3
125 000	40	0.23	0.08	0.16	0.16	1
126 000	40	0.55	0.37	0.54	0.54	2
127 000	80	1.27	0.66	0.85	0.85	4
128 000	160	0.37	0.39	0.23	0.54	3
129 000	320	0.18	0.43	0.00	0.58	3
130 000	40	1.04	0.65	0.09	0.09	1
131 000	160	0.35	0.40	0.23	0.43	2
132 000	80	1.68	0.99	0.91	0.91	4
133 000	40	0.93	0.62	0.54	0.54	2
134 000	80	0.57	0.18	0.16	0.51	3
135 000	40	0.39	0.27	0.85	0.85	4
136 000	40	1.02	0.68	0.85	0.85	4
137 000	40	0.54	0.35	0.23	0.23	2
138 000	280	1.29	0.59	0.23	0.66	3
139 000	240	1.21	0.62	0.23	0.74	3
140 000	80	0.81	0.67	0.54	0.69	3
141 000	40	1.75	1.30	0.91	0.91	4
142 000	200	1.47	0.67	0.85	0.84	4
143 000	40	1.95	1.32	0.85	0.85	4
144 000	40	1.18	0.78	0.85	0.85	4
145 000	160	1.97	0.88	0.80	0.84	4
146 000	40	0.76	0.50	0.85	0.85	4
147 000	80	1.81	0.81	0.85	0.85	4

Nutrient Analysis
Chemical Oxygen Demand

		Sediment		Water Soluble		
Cell Num Div	Drainage Area (acres)	Within Cell (lbs/a)	Cell Outlet (lbs/a)	Within Cell (lbs/a)	Cell Outlet (lbs/a)	Conc (ppm)
1 000	40			24.00	24.29	105
2 000	40			24.00	24.29	105
3 000	80			13.00	18.51	97
4 000	80			13.00	18.43	87
5 000	40			24.00	24.29	105
6 000	40			24.00	24.29	105
7 000	40			24.00	24.29	105
8 000	40			24.00	24.29	105
9 000	40			24.00	24.29	105
10 000	40			24.00	24.29	105
11 000	120			20.00	18.90	93
12 000	440			5.35	0.00	0
13 000	80			15.73	0.00	0
14 000	40			15.00	15.04	65
15 000	120			24.00	24.29	105
16 000	80			27.00	25.59	111
17 000	120			24.00	25.16	109
18 100	130			24.00	25.09	108
18 200	5360			0.00	18.90	83
18 300	10			24.00	24.29	105
18 400	5180			0.00	18.74	82
19 000	80			20.00	21.98	95
20 000	200			13.00	14.29	71
21 000	40			24.00	24.29	105
22 000	160			24.00	21.98	95
23 000	40			24.00	24.29	105
24 000	160			20.00	23.13	100
25 000	40			20.00	19.66	85
26 000	80			20.00	19.66	85
27 000	120			24.00	21.21	92
28 100	10			19.00	19.20	83
28 200	5160			0.00	18.76	83
28 300	130			19.00	21.05	91
28 400	5140			0.00	18.80	83
29 100	10			22.00	21.88	42
29 200	20			12.00	12.96	81
29 300	4980			0.00	18.80	83
29 400	30			0.00	8.64	31
30 100	10			14.00	13.60	85
30 200	10			14.00	13.60	85
30 300	10			0.00	0.00	0
30 400	20			14.00	13.60	85
31 000	40			20.00	19.66	85
32 000	40			1.00	1.16	5
33 000	80			14.00	7.38	38
34 000	80			24.00	24.29	105
35 000	280			24.00	22.97	99
36 000	40			15.00	15.04	65
37 000	200			24.00	23.37	101
38 100	210			20.00	23.19	100
38 200	10			24.00	24.29	105
38 300	220			24.00	23.24	100
38 400	240			0.00	22.32	95
39 100	10			20.00	19.66	85
39 200	10			7.00	7.00	85
39 300	20			0.00	9.83	43
39 400	20			0.00	3.50	22
40 100	10			20.00	19.66	85
40 200	10			20.00	19.66	85
40 300	20			10.00	14.70	77
40 400	20			0.00	9.83	63
41 100	10			5.00	5.10	62
41 200	20			22.00	13.37	60
41 300	10			10.00	9.74	65
41 400	20			14.00	11.81	62
42 000	4930			0.00	18.89	84
43 100	130			0.00	16.43	63

43 200	90	11.00	20.71	92
43 300	2210	0.00	19.88	93
43 400	10	9.00	9.29	62
44 000	80	24.00	21.98	95
45 000	40	24.00	24.29	105
46 000	320	24.00	23.13	100
47 000	400	15.00	21.52	93
48 000	760	20.00	19.87	94
49 100	780	24.00	19.98	94
49 200	1070	24.00	20.71	95
49 300	770	24.00	19.93	94
49 400	40	24.00	24.29	105
50 100	1370	0.00	20.38	87
50 200	1420	0.00	19.98	85
50 300	270	19.00	20.60	71
50 400	20	20.00	19.32	84
51 100	1460	0.00	19.80	84
51 200	1500	5.00	19.60	84
51 300	10	24.00	24.29	105
51 400	10	24.00	24.29	105
52 100	1510	24.00	19.63	84
52 200	1530	0.00	19.53	83
52 300	10	24.00	24.29	105
52 400	10	19.00	18.97	82
53 000	2530	0.00	18.51	82
54 100	2190	0.00	20.02	94
54 200	2180	0.00	20.11	95
54 300	10	14.00	13.88	60
54 400	2170	0.00	20.20	96
55 000	2160	24.00	20.30	96
56 000	40	24.00	24.29	105
57 000	80	24.00	24.29	105
58 000	120	24.00	24.29	105
59 000	320	7.00	17.84	96
60 100	10	24.00	24.29	105
60 200	30	24.00	24.29	105
60 300	10	24.00	24.29	105
60 400	10	30.00	30.48	105
61 100	260	19.00	20.66	71
61 200	10	19.00	18.97	82
61 300	250	0.00	20.73	71
61 400	10	55.00	54.70	105
62 000	40	20.00	19.66	85
63 000	90	13.00	17.10	88
64 100	880	0.00	18.55	93
64 200	60	0.00	5.03	27
64 300	780	5.00	18.96	95
64 400	10	5.00	5.35	65
65 100	40	0.00	6.21	37
65 200	20	5.00	8.92	77
65 300	10	7.00	7.00	85
65 400	10	13.00	12.73	85
66 000	2120	24.00	20.22	96
67 000	80	16.00	20.01	105
68 000	40	24.00	24.29	105
69 000	40	24.00	24.29	105
70 000	80	13.00	18.51	97
71 000	160	13.00	15.62	92
72 100	20	24.00	24.29	105
72 200	80	13.00	24.15	104

72 300	10	24.00	24.29	105
72 400	50	24.00	26.37	114
73 100	220	0.00	19.68	70
73 200	110	0.00	17.89	60
73 300	20	19.00	21.52	73
73 400	90	0.00	21.27	72
74 100	10	5.00	5.35	65
74 200	10	24.00	24.29	105
74 300	10	20.00	19.66	85
74 400	10	24.00	24.29	105
75 000	40	24.00	24.29	105
76 000	770	5.00	19.13	95
77 000	40	24.00	24.29	105
78 000	1960	16.00	20.06	95
79 000	40	24.00	24.29	105
80 000	480	24.00	21.91	95
81 000	440	24.00	21.69	94
82 000	400	20.00	21.43	93
83 000	40	24.00	24.29	105
84 000	40	13.00	12.73	85
85 000	40	27.00	26.89	116
86 100	10	24.00	24.29	105
86 200	70	0.00	24.54	90
86 300	50	24.00	29.50	127
86 400	60	24.00	28.63	124
87 000	330	24.00	20.03	98
88 000	40	15.00	15.04	65
89 000	690	12.00	19.63	95
90 000	40	24.00	24.29	105
91 000	1840	24.00	19.98	94
92 000	1080	24.00	20.72	94
93 000	1000	24.00	20.62	94
94 000	80	24.00	21.98	95
95 000	40	20.00	19.66	85
96 000	320	20.00	21.87	95
97 000	40	31.00	30.80	133
98 000	240	24.00	18.44	96
99 000	280	24.00	19.27	97
100 000	570	24.00	20.18	99
101 000	610	24.00	20.45	99
102 000	240	20.00	18.90	93
103 000	680	20.00	18.28	94
104 000	40	20.00	19.66	85
105 000	360	20.00	18.30	91
106 000	40	20.00	19.66	85
107 000	40	20.00	19.66	85
108 000	280	20.00	22.19	96
109 000	80	24.00	24.29	105
110 000	40	24.00	24.29	105
111 000	200	20.00	17.27	93
112 000	80	13.00	12.73	85
113 000	200	29.00	19.59	99
114 000	40	24.00	24.29	105
115 000	200	20.00	18.74	94
116 000	360	13.00	18.33	98
117 000	40	13.00	12.73	85
118 000	320	15.00	18.13	92
119 000	40	20.00	19.66	85
120 000	80	22.00	20.97	91
121 000	120	21.00	20.83	90

LOON LAKE AGNPS OUTPUT

122	000	160	25.00	21.77	94
123	000	40	24.00	24.29	105
124	000	160	5.00	16.67	96
125	000	40	13.00	12.73	85
126	000	40	20.00	19.66	85
127	000	80	24.00	24.29	105
128	000	160	13.00	18.51	97
129	000	320	5.00	19.03	99
130	000	40	7.00	7.00	85
131	000	160	13.00	15.92	92
132	000	80	24.00	23.13	100
133	000	40	20.00	19.66	85
134	000	80	13.00	18.51	97
135	000	40	24.00	24.29	105
136	000	40	24.00	24.29	105
137	000	40	13.00	12.73	85
138	000	280	13.00	20.99	101
139	000	240	13.00	22.37	103
140	000	80	20.00	21.98	95
141	000	40	22.00	21.98	95
142	000	200	24.00	24.29	105
143	000	40	24.00	24.29	105
144	000	40	24.00	24.29	105
145	000	160	24.00	24.29	105
146	000	40	24.00	24.29	105
147	000	80	24.00	24.29	105

Watershed Summary

Watershed Studied	Goose Lake
The area of the watershed is	1280 acres
The area of each cell is	40.00 acres
The characteristic storm precipitation is	2.30 inches
The storm energy-intensity value is	16

Values at the Watershed Outlet

Cell number	9 100
Runoff volume	0.9 inches
Peak runoff rate	343 cfs
Total Nitrogen in sediment	0.12 lbs/acre
Total soluble Nitrogen in runoff	2.69 lbs/acre
Soluble Nitrogen concentration in runoff	12.72 ppm
Total Phosphorus in sediment	0.06 lbs/acre
Total soluble Phosphorus in runoff	0.54 lbs/acre
Soluble Phosphorus concentration in runoff	2.56 ppm
Total soluble chemical oxygen demand	18.32 lbs/acre
Soluble chemical oxygen demand concentration in runoff	87 ppm

Feedlot Analysis

Cell # 19 000

Nitrogen concentration (ppm)	300.000
Phosphorus concentration (ppm)	62.560
COD concentration (ppm)	4500.000
Nitrogen mass (lbs)	17.351
Phosphorus mass (lbs)	3.618
COD mass (lbs)	260.268

Animal feedlot rating number 0

Sediment Analysis

Particle type	Area Weighted Erosion Upland (t/a)	Area Weighted Erosion Channel (t/a)	Delivery Ratio (%)	Enrichment Ratio	Mean Concentration (ppm)	Area Weighted Yield (t/a)	Yield (tons)
CLAY	0.03	0.00	62	16	168.10	0.02	22.7
SILT	0.04	0.00	0	0	1.43	0.00	0.2
SAGG	0.25	0.00	0	0	1.77	0.00	0.2
LAGG	0.15	0.00	1	0	11.38	0.00	1.5
SAND	0.05	0.00	1	0	3.57	0.00	0.5
TOTAL	0.50	0.00	4	1	186.25	0.02	25.2

-HYDR- Cell Num Div	Drainage Area (acres)	Overland Runoff (in.)	Upstream Runoff (in.)	Peak Flow Upstream (cfs)	Downstream Runoff (in.)	Peak Flow Downstream (cfs)
1 000	40	1.02	0.00	0	1.02	76
2 000	40	0.66	0.00	0	0.66	48
3 000	40	1.02	0.00	0	1.02	75
4 000	40	0.66	0.00	0	0.66	47
5 000	40	0.66	0.00	0	0.66	47
6 000	40	1.02	0.00	0	1.02	70
7 000	120	0.66	0.84	116	0.78	100
8 000	360	1.28	0.76	156	0.82	168
9 100	1280	0.66	0.94	356	0.93	343
9 200	10	1.02	0.00	0	1.02	18
9 300	1270	2.30	0.92	399	0.94	387
9 400	370	0.66	0.91	120	0.90	113
10 000	360	1.02	0.89	184	0.91	187
11 000	280	1.02	0.91	178	0.92	180
12 000	200	1.02	0.94	143	0.96	153
13 000	40	1.02	0.00	0	1.02	71
14 000	40	0.66	0.00	0	0.66	48
15 000	160	0.33	0.80	83	0.68	75
16 100	520	2.30	0.99	202	1.01	198
16 200	10	0.66	0.00	0	0.66	11
16 300	500	2.30	0.97	155	1.00	155
16 400	210	0.66	1.02	79	1.00	76
17 000	200	1.02	1.02	118	1.02	130
18 000	160	1.02	1.02	106	1.02	126
19 000	80	1.02	0.71	51	0.86	76
20 000	40	1.02	0.00	0	1.02	67
21 000	80	0.71	1.02	73	0.86	84
22 000	280	0.46	1.02	187	0.94	180
23 000	120	1.02	1.02	94	1.02	117
24 000	120	1.02	1.02	94	1.02	112
25 000	40	0.71	0.00	0	0.71	53
26 000	40	1.02	0.00	0	1.02	71
27 000	120	1.02	1.02	138	1.02	131
28 000	80	1.02	1.02	80	1.02	99
29 000	80	1.02	1.02	77	1.02	95
30 000	40	1.02	0.00	0	1.02	74
31 000	40	1.02	0.00	0	1.02	77
32 000	40	1.02	0.00	0	1.02	73

Condensed Soil Loss

Cell Num Div	Drainage Area (acres)	RUNOFF Volume (in.)	Generated Above (%)	Peak Rate (cfs)	Cell Erosion (t/a)	SEDIMENT Generated Above (tons)	Generated Within (tons)	Yield (tons)	Depo (%)
1 000	40	1.02	0.0	76	0.85	0.00	34.13	19.06	44
2 000	40	0.66	0.0	48	0.34	0.00	13.45	2.73	80
3 000	40	1.02	0.0	75	0.35	0.00	13.82	3.17	77
4 000	40	0.66	0.0	47	0.30	0.00	12.02	2.40	80
5 000	40	0.66	0.0	47	0.39	0.00	15.47	7.97	48
6 000	40	1.02	0.0	70	0.29	0.00	11.54	6.38	45
7 000	120	0.66	71.8	100	0.18	21.78	7.30	11.79	59
8 000	360	1.28	82.6	168	0.00	21.44	0.00	15.20	29
9 100	1280	0.66	99.4	343	0.00	39.12	0.00	25.20	36
9 200	10	1.02	0.0	18	0.00	0.00	0.03	0.16	-81
9 300	1270	2.30	98.1	387	0.00	48.51	0.00	39.12	19
9 400	370	0.66	98.0	113	0.00	31.16	0.00	10.58	66
10 000	360	1.02	87.5	187	0.29	37.66	11.45	31.16	37
11 000	280	1.02	84.2	180	0.52	37.10	20.96	35.25	39
12 000	200	1.02	78.7	153	0.38	30.89	15.30	29.13	37
13 000	40	1.02	0.0	71	0.62	0.00	24.69	13.49	45
14 000	40	0.66	0.0	48	0.17	0.00	6.93	3.66	47
15 000	160	0.33	87.8	75	0.00	15.49	0.00	6.48	58
16 100	520	2.30	95.6	198	0.00	25.78	0.00	22.58	12
16 200	10	0.66	0.0	11	0.00	0.00	0.00	0.00	-100
16 300	500	2.30	95.4	155	0.00	62.68	0.00	25.78	59

16 400	210	0.66	96.9	76	0.00	40.36	0.00	6.04	85
17 000	200	1.02	80.0	130	0.33	51.48	13.21	40.36	38
18 000	160	1.02	75.0	126	0.93	41.42	37.07	51.48	34
19 000	80	1.02	40.9	76	0.37	10.73	14.97	11.02	57
20 000	40	1.02	0.0	67	0.36	0.00	14.32	7.75	46
21 000	80	0.71	59.1	84	0.36	7.75	14.35	11.83	46
22 000	280	0.46	93.0	180	0.00	77.84	0.00	56.64	27
23 000	120	1.02	66.7	117	0.55	49.14	21.97	43.56	39
24 000	120	1.02	66.7	112	0.74	39.84	29.41	41.42	40
25 000	40	0.71	0.0	53	0.44	0.00	17.68	10.73	39
26 000	40	1.02	0.0	71	0.56	0.00	22.33	12.21	45
27 000	120	1.02	66.7	131	0.81	30.82	32.38	34.28	46
28 000	80	1.02	50.0	99	1.79	27.74	71.62	49.14	51
29 000	80	1.02	50.0	95	1.38	21.19	55.22	39.84	48
30 000	40	1.02	0.0	74	0.74	0.00	29.43	18.60	37
31 000	40	1.02	0.0	77	1.24	0.00	49.58	27.74	44
32 000	40	1.02	0.0	73	0.84	0.00	33.61	21.19	37

Nutrient Analysis
N I T R O G E N

		Sediment		Water Soluble		
Cell Num Div	Drainage Area (acres)	Within Cell (lbs/a)	Cell Outlet (lbs/a)	Within Cell (lbs/a)	Cell Outlet (lbs/a)	Conc (ppm)
1 000	40	2.79	1.75	4.67	4.67	20
2 000	40	1.12	0.31	1.48	1.48	10
3 000	40	1.15	0.35	2.15	2.15	9
4 000	40	1.03	0.28	1.32	1.32	9
5 000	40	1.48	0.87	1.83	1.83	12
6 000	40	1.17	0.73	2.68	2.68	12
7 000	120	0.69	0.42	0.92	2.36	13
8 000	360	0.00	0.21	0.26	1.80	10
9 100	1280	0.00	0.12	0.13	2.69	13
9 200	10	0.03	0.12	1.86	1.86	8
9 300	1270	0.00	0.17	0.55	2.71	13
9 400	370	0.00	0.16	0.13	2.90	14
10 000	360	1.16	0.45	4.14	2.97	14
11 000	280	1.89	0.60	4.14	3.04	15
12 000	200	1.47	0.68	4.14	3.06	14
13 000	40	2.15	1.33	4.14	4.14	18
14 000	40	0.78	0.47	1.20	1.20	8
15 000	160	0.00	0.24	0.07	1.69	11
16 100	520	0.00	0.30	0.42	3.26	14
16 200	10	0.00	0.00	0.13	0.13	1
16 300	500	0.00	0.34	0.42	3.38	15
16 400	210	0.00	0.16	0.13	3.60	16
17 000	200	1.30	0.88	4.14	3.77	16
18 000	160	2.98	1.28	4.14	3.68	16
19 000	80	1.44	0.65	3.11	2.17	11
20 000	40	1.39	0.85	4.14	4.14	18
21 000	80	1.39	0.69	1.34	2.74	14
22 000	280	0.00	0.88	0.09	3.32	16
23 000	120	1.96	1.41	2.68	3.65	16
24 000	120	2.84	1.55	2.53	3.53	15
25 000	40	1.89	1.27	1.24	1.24	8
26 000	40	1.98	1.22	4.14	4.14	18
27 000	120	2.67	1.16	4.14	4.07	18
28 000	80	5.04	2.14	4.14	4.14	18
29 000	80	4.09	1.81	4.14	4.03	17
30 000	40	2.85	1.97	3.91	3.91	17
31 000	40	3.76	2.36	4.14	4.14	18
32 000	40	3.17	2.19	3.91	3.91	17

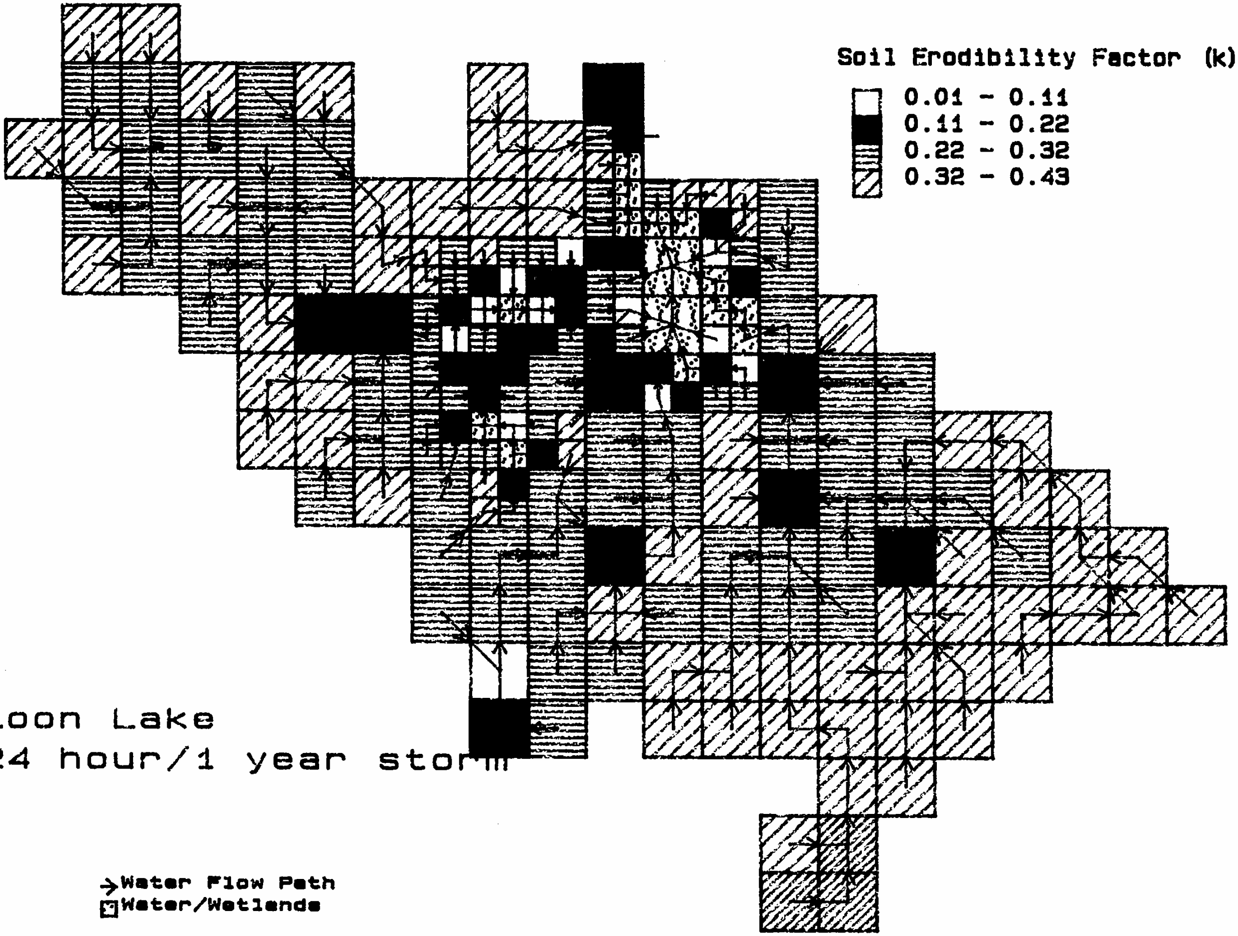
Nutrient Analysis
P H O S P H O R U S

		Sediment		Water Soluble		
Cell Num Div	Drainage Area (acres)	Within Cell (lbs/a)	Cell Outlet (lbs/a)	Within Cell (lbs/a)	Cell Outlet (lbs/a)	Conc (ppm)
1 000	40	1.39	0.87	0.96	0.96	4
2 000	40	0.56	0.16	0.29	0.29	2
3 000	40	0.57	0.18	0.43	0.43	2
4 000	40	0.51	0.14	0.26	0.26	2
5 000	40	0.74	0.44	0.36	0.36	2
6 000	40	0.59	0.36	0.54	0.54	2
7 000	120	0.35	0.21	0.17	0.47	3
8 000	360	0.00	0.11	0.01	0.36	2
9 100	1280	0.00	0.06	0.01	0.54	3
9 200	10	0.01	0.06	0.36	0.36	2
9 300	1270	0.00	0.08	0.03	0.54	3
9 400	370	0.00	0.08	0.01	0.58	3
10 000	360	0.58	0.22	0.85	0.60	3
11 000	280	0.94	0.30	0.85	0.61	3
12 000	200	0.73	0.34	0.85	0.62	3
13 000	40	1.08	0.66	0.85	0.85	4
14 000	40	0.39	0.23	0.23	0.23	2
15 000	160	0.00	0.12	0.00	0.33	2
16 100	520	0.00	0.15	0.00	0.66	3
16 200	10	0.00	0.00	0.01	0.01	0
16 300	500	0.00	0.17	0.01	0.69	3
16 400	210	0.00	0.08	0.01	0.73	3
17 000	200	0.65	0.44	0.85	0.77	3
18 000	160	1.49	0.64	0.85	0.75	3
19 000	80	0.72	0.32	0.63	0.43	2
20 000	40	0.70	0.43	0.85	0.85	4
21 000	80	0.70	0.34	0.26	0.55	3
22 000	280	0.00	0.44	0.01	0.68	3
23 000	120	0.98	0.70	0.54	0.74	3
24 000	120	1.42	0.78	0.51	0.72	3
25 000	40	0.95	0.63	0.24	0.24	1
26 000	40	0.99	0.61	0.85	0.85	4
27 000	120	1.34	0.58	0.85	0.83	4
28 000	80	2.52	1.07	0.85	0.85	4
29 000	80	2.05	0.91	0.85	0.82	4
30 000	40	1.42	0.99	0.80	0.80	3
31 000	40	1.88	1.18	0.85	0.85	4
32 000	40	1.58	1.09	0.80	0.80	3

Nutrient Analysis
Chemical Oxygen Demand

		Sediment		Water Soluble		
Cell Num Div	Drainage Area (acres)	Within Cell (lbs/a)	Cell Outlet (lbs/a)	Within Cell (lbs/a)	Cell Outlet (lbs/a)	Conc (ppm)
1 000	40			22.00	21.98	95
2 000	40			14.00	14.23	95
3 000	40			19.00	19.20	83

4 000	40	16.00	15.73	105
5 000	40	16.00	15.73	105
6 000	40	20.00	19.66	85
7 000	120	12.00	15.91	90
8 000	360	12.00	14.69	79
9 100	1280	0.00	18.32	87
9 200	10	13.00	13.19	57
9 300	1270	0.00	18.47	87
9 400	370	0.00	20.33	100
10 000	360	24.00	20.90	102
11 000	280	24.00	21.15	101
12 000	200	24.00	21.60	100
13 000	40	24.00	24.29	105
14 000	40	13.00	12.73	85
15 000	160	2.00	13.28	86
16 100	520	0.00	20.21	88
16 200	10	0.00	0.00	0
16 300	500	0.00	21.01	93
16 400	210	0.00	22.25	98
17 000	200	24.00	23.37	101
18 000	160	24.00	23.13	100
19 000	80	26.00	19.89	102
20 000	40	24.00	24.29	105
21 000	80	14.00	18.95	97
22 000	280	5.00	20.83	98
23 000	120	20.00	22.75	98
24 000	120	20.00	22.75	98
25 000	40	14.00	13.60	85
26 000	40	24.00	24.29	105
27 000	120	24.00	24.29	105
28 000	80	24.00	24.29	105
29 000	80	24.00	24.29	105
30 000	40	24.00	24.29	105
31 000	40	24.00	24.29	105
32 000	40	24.00	24.29	105



Loon Lake
24 hour/1 year storm

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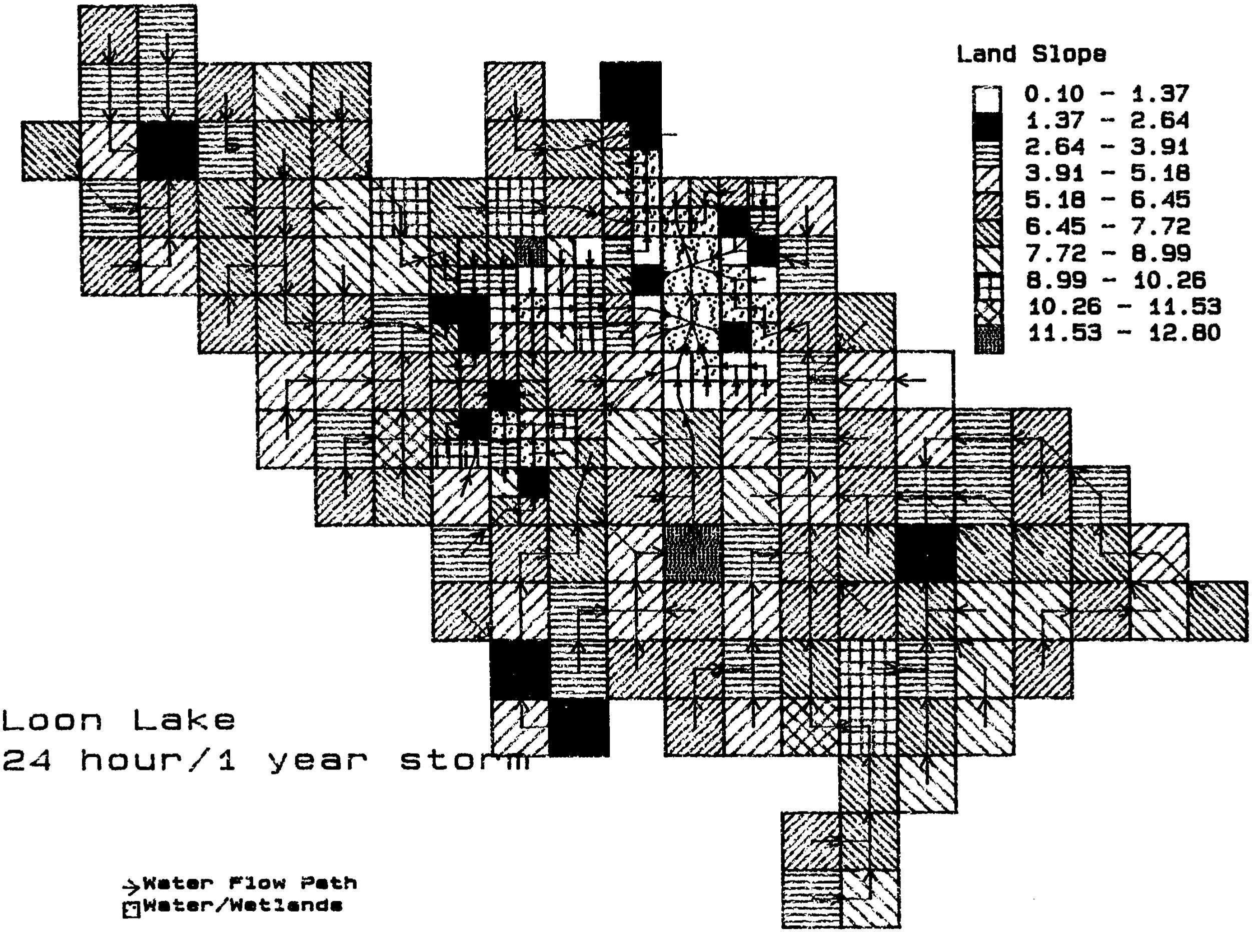

Loon Lake
24 hour/1 year storm

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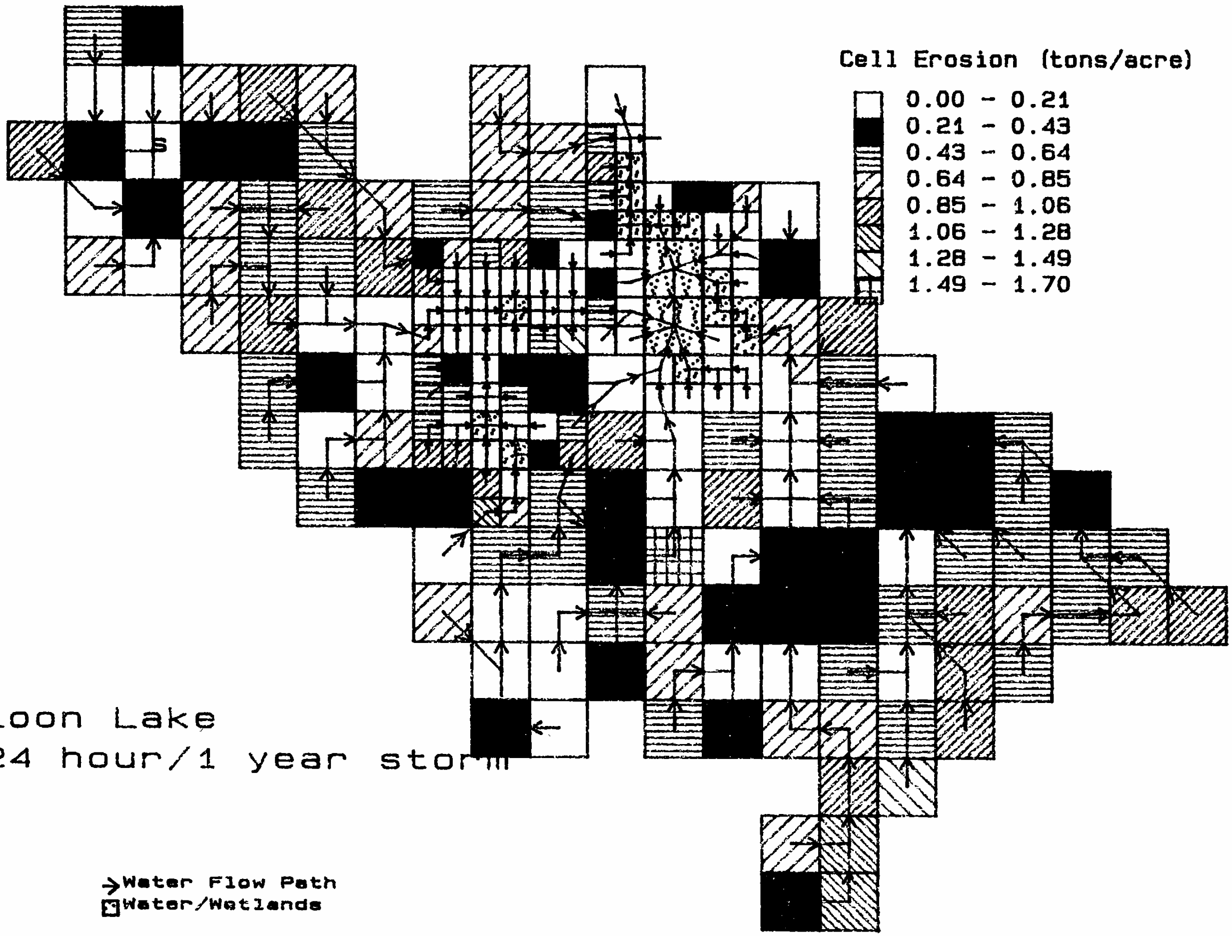

Loon Lake
24 hour/1 year storm

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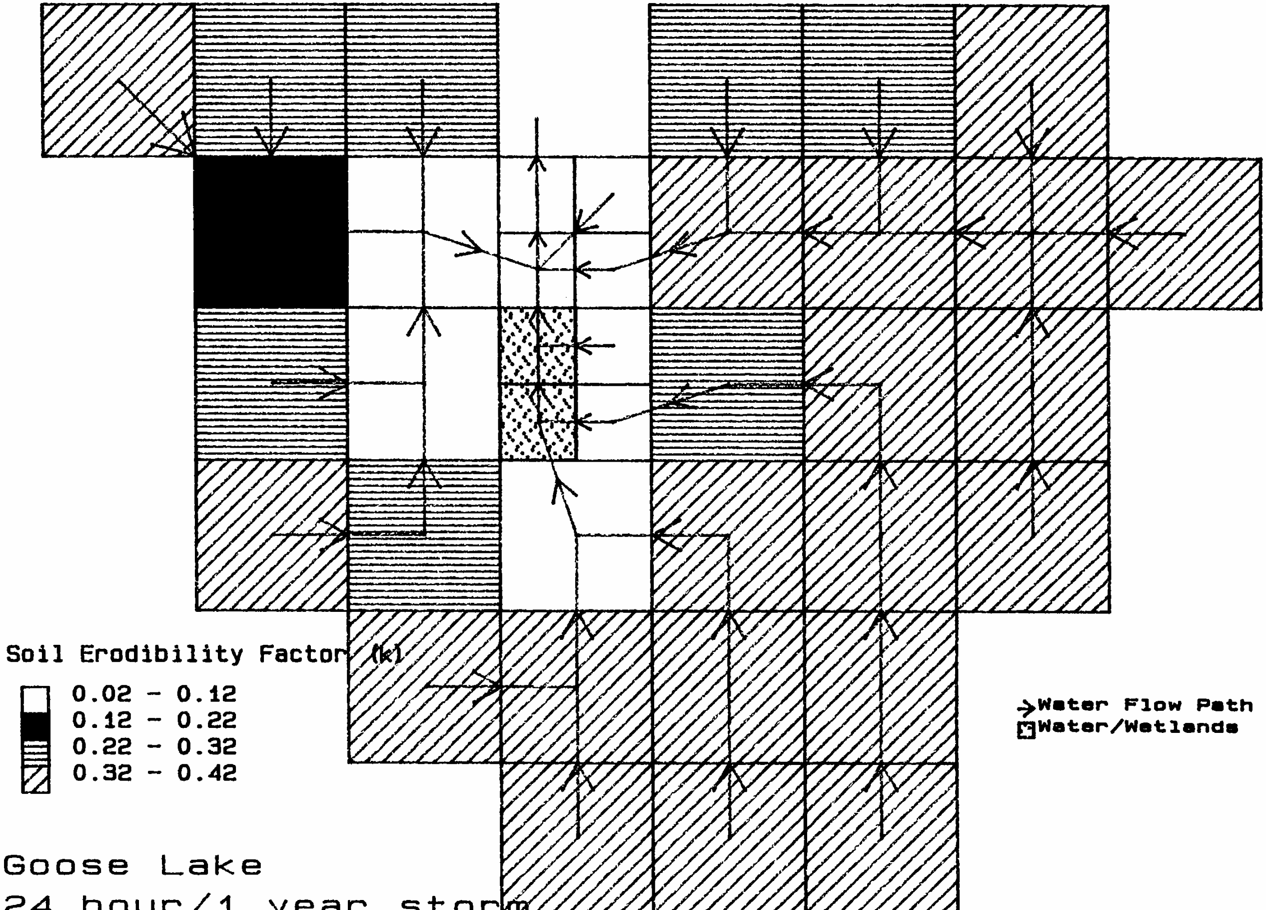

Goose Lake
24 hour/1 year storm

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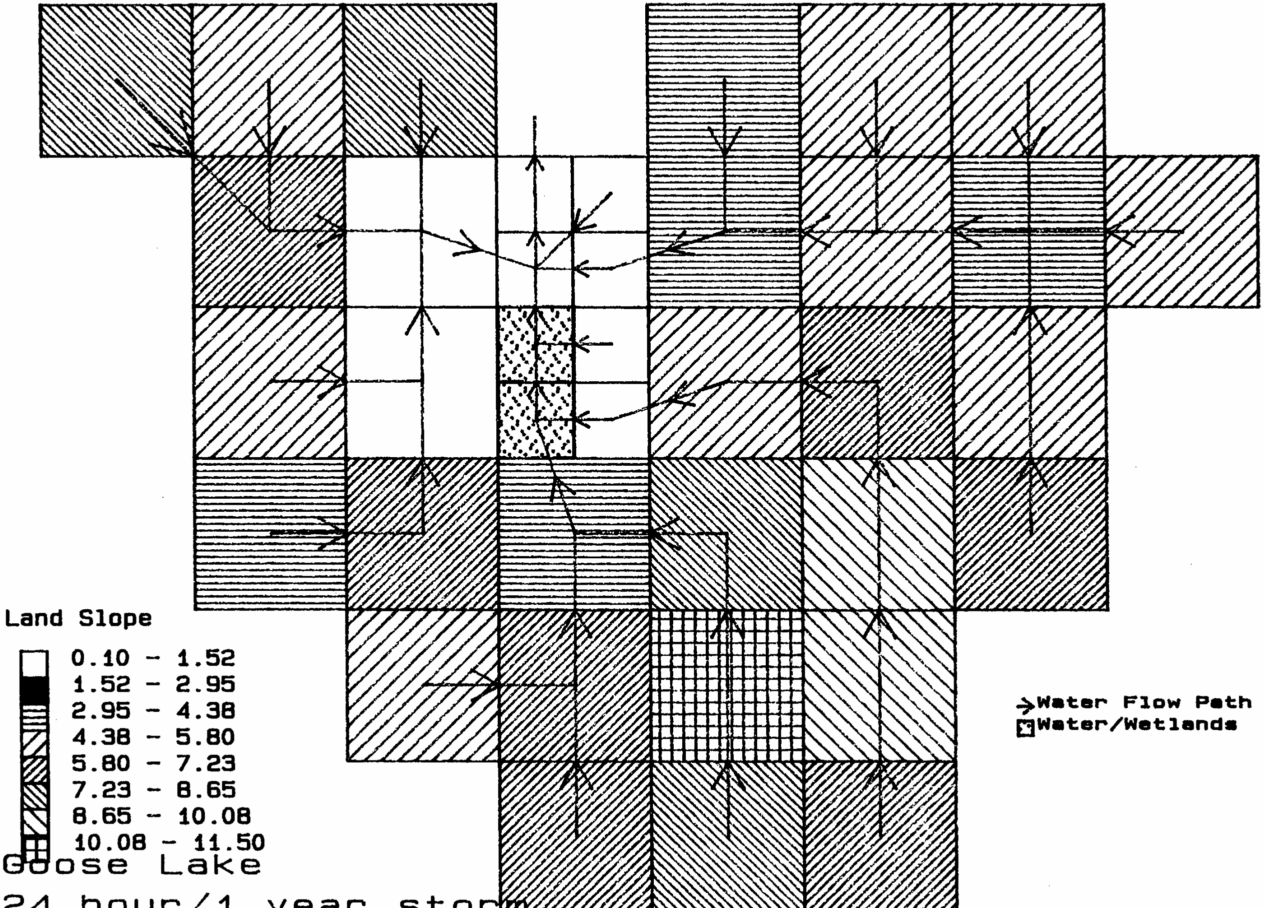

Goose Lake

24 hour/1 year storm

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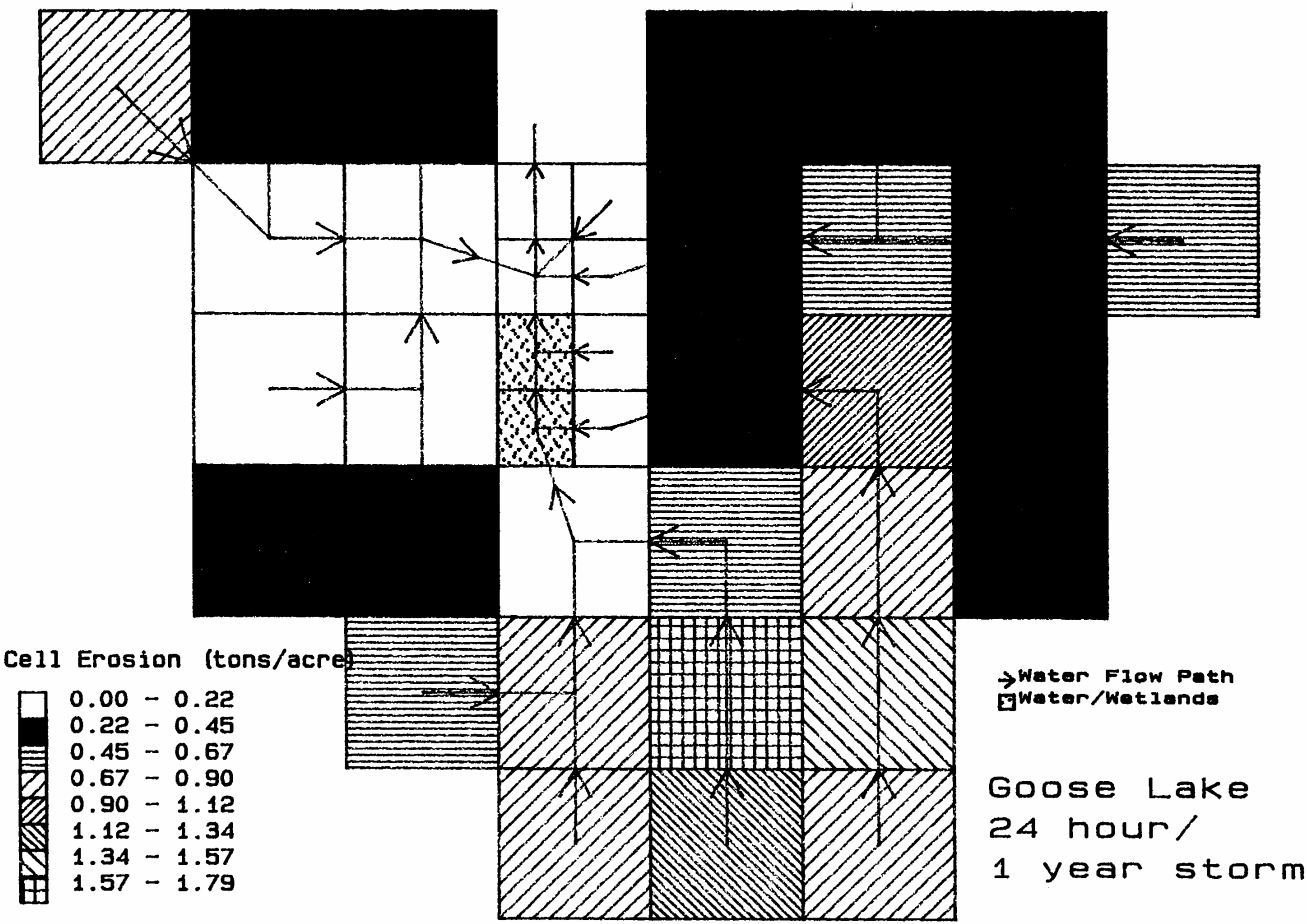

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